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FINDING THE OPTIMUM DESIGNS OF ARBITRARY TEM-MODE QUADRATURE COUPLERS AND PHASE SHIFTERS, USING A DIGITAL COMPUTER

By

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ABSTRACT. This report discloses the full FORTRAN IV program (for an IBM 7094 digital computer) for the automatic design of arbitrary TEM quadrature couplers and differential phase shifters. The design is completely general in the sense that any number of coupled quarter wavelength sections, any nominal coupling value (or phase shift), and any design bandwidth of operation can be realized, although the user may specify any maximum coupling value in the design. This last degree of freedom in the specification to the machine, which is all-important in the physical realization of a theoretical design, is met by finding the proper number and types of tandem coupled junctions in the solution. This computer solution will be optimum. It will find the least ripple for the required bandwidth of operation for any (input) design complexity.

This report shows a complete flow chart of the total program. It also gives the special subroutines developed for automatic plotting of the coupler (or phase shifter) frequency-response functions. Various sample input data and machine outputs are also included.

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FOREWORD

This report discloses the full FORTRAN 1V program, as used on an IBM 7094 digital computer at NOTS, for the automatic design of some 1000 arbitrary TEM quadrature couplers and differential phase shifters. The following listing of the program, complete with comment cards for explanations, was made on the machine in order that no typographical errors should be made. For the benefit of the readers who do not have a similar computing facility and thereby must modify this program, a complete flow chart is included; to the rest of the readers, the author apologizes for the excessive length of this report.

Work was accomplished on BuWeps Task RMGA-61-158/216-1/W1132 and RM-3781-001/216-1/WW115-00-001.

This report has been reviewed for technical accuracy by Robert G. Corzine and William Hughey.

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CONTENTS

Section 1. INTRODUCTION

During the last decade, before the directional couplers attained their present peak of popularity, there has truely been a host of papers on this subject. (Ref. 1-10.) However, aside from the question of which published designs could, in fact, be built in practice, there still existed the need for high-quality (i.e., low ripple) extremely broad band couplers. Furthermore, because of the recently developed antenna feed matrices and receiver techniques, the quadrature relationship in some couplers and differential phase shifters are now applied in a multitude of microwave system designs.

This paper is primarily directed to the system design engineers who require arbitrary bandwidth, arbitrary ripple (or quality) performance, arbitrary but specifically controllable construction constraints on devices and still have an optimum solution. The paper is prepared for the engineer who does not care about the details of coupler synthesis, but only in what the solution and performance is for some given requirement and some physical constraint. It is beyond the scope of this report to delve into the synthesis of such arbitrary couplers and phase shifters.[1]

The explanation given on the comment cards in the beginning of the program were judged to be sufficiently complete so that any reader may be able to apply the program. This explanation became necessary when, in order to make the program more flexible, it was modified to accept several types of input data. With the enclosed examples, there should be no difficulty in using the program.

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[1]Such is the purpose of a future paper: Shelton, J.P. and J.A. Mosko. "Synthesis and Design of Wide-Band Equal-Ripple TEM Direction Couplers and Fixed Phase Shifters," IEEE TRANS, Vol. MTT-14, No. 10 (October 1966).

Section 2. PROGRAM LISTING

The following text is a listing of the FORTRAN IV program (main program and subroutines) to design TEM couplers and phase shifters.

A casual glance at the text will reveal that not all subroutines are disclosed in detail. Those missing are non-essential in the sense that they are used to plot and label responses and write comments using the SC4020 plotting equipment. If this plotting system is not available, SCOUT V, TABL IV, AICRT 3, etc., and SUB ROUTINE PLOT would not be reproduced.

Note that tapes 5, 6, and 7 are for input data, written output, and punched card output. Also, tapes 16 and 18 are for written output (comments, labels, etc.) using the SC4020 plotted output.

Finally, the first five data cards, which are shown to be read in, are for comments and labeling of plots: these are non-essential and therefore can be blank cards or the read and write instructions can be removed altogether.

```
      20210  DECK
C
C     TITLE  DESIGN OF SYMMETRICAL TEM COUPLERS AND DIFFERENTIAL
C                          PHASE SHIFTERS
C
C           THIS PROGRAM IS TO DESIGN TEM QUADRATURE COUPLERS AND
C     DIFFERENTIAL PHASE SHIFTERS OPERATING OVER ARBITRARY BANDWIDTHS,
C     ANY NOMINAL COUPLING OR PHASE SHIFT, TO ANY DEGREE OF DESIGN
C     TOLERANCE, AND FOR ANY SPECIFIED MAXIMUM VOLTAGE COUPLING
C     COEFFICIENT (SPECIFIED BY THE DESIRED METHOD OF CONSTRUCTION
C     OF THE COUPLERS OR PHASE SHIFTERS).
C           THE PROGRAM, BY MEANS OF AN ITERATIVE SOLUTION, WILL GIVE
C     THE NORMALIZED EVEN MODE IMPEDANCES (ALSO THE NORMALIZED VOLTAGE
C     COUPLING COEFFICIENTS) OF THE INDIVIDUAL QUARTER-WAVELENGTH
C     COUPLED SECTIONS.  BECAUSE OF COUPLER SYMMETRY, ONLY HALF OF THE
C     COUPLING VALUES ARE GIVEN (OBVIOUSLY, ALL THE ESSENTIAL ONES).
C     THIS PROGRAM BY USING THE SC4020 PLOTTER, WILL PLOT THE SOLUTION
C     AND DISPLAY THE COUPLING VALUES ON THE SAME FRAME AUTOMATICALLY.
C
C
C           DEFINITION OF SYMBOLS
C
C     K       IS THE SPECIFIC DESIGN PROBLEM CODE, I.E.
C             K = 0 FOR PHASE SHIFTERS
C             K = 1 FOR COUPLERS.
C     NMOST   IS THE MAXIMUM NUMBER OF CASCADED SECTIONS IN THE LARGEST
C             (OR,SOMETIMES,ONLY) TANDEM COUPLER/PHASE SHIFTER DESIGN.
C     N       EQUALS NMOST FOR PHASE SHIFTERS, AND
C             EQUALS ((1/2)*(NMOST+1) ) FOR COUPLERS.
C             (NOTE THAT N SIMPLY EQUALS THE LARGEST NUMBER OF DIFFERENT
C             IMPEDANCES OF THE LARGEST DEVICE).
C     NEND    IS THE END DATA CARD (I.E. IF NEND IS NON-ZERO, GO TO
C             END).
C     ITEMAX  IS THE NUMBER OF MAXIMUM ALLOWABLE ITERATIONS.
C     THETA   IS THE NORMALIZED FREQUENCY IN DEGREES (CENTER FREQUENCY =
C             90.0 DEGREES).
C     DELTA   IS THE INCREMENTAL THETA FOR COMPUTATIONS OF RESPONSE, AND
C             EQUALS 90 DEGREES DIVIDED BY ANY INTEGER.
C     UO      IS THE NOMINAL COUPLING FOR COUPLERS (IN DEGREES) OR THE
C             NOMINAL PHASE SHIFT FOR PHASE SHIFTERS (ALSO IN DEGREES).
C     TOL     IS THE REQUIRED TOLERANCE, OR HOW CLOSE THE EQUAL RIPPLE
C             PERFORMANCE MUST BE - - - READ IT IN PERCENT OF THE AVERAGE
C             RIPPLE.
C     ZMAX    IS THE MAXIMUM ALLOWABLE NORMALIZED EVEN MODE IMPEDANCE
C             OF ANY SECTION.
C     BW      IS THE DESIGN BANDWIDTH RATIO.
C     CONT    IS A CONTINUE CODE IN THE SENSE THAT THE STARTING
C             SOLUTION OF A NEW DESIGN PROBLEM SHOULD BE THE LAST
C             SOLUTION OF THE PRESENTLY COMPLETED PROBLEM.
C
C     IZCASE  IS A STARTING DATA CODE.  IF NON-ZERO, THIS MEANS THAT
C             THE INPUT DATA FOR THE STARTING SOLUTION IS IN TERMS OF
C             EVEN MODE IMPEDANCES AND NOT IN REFLECTION COEFFICIENTS.
C             IF ZERO (OR BLANK), THE STARTING DATA IS     IN TERMS OF
C             REFLECTION COEFFICIENTS, OR ANTENNA ELEMENT DISTRIBUTIONS.
C     M       IS THE NUMBER OF TANDEM COUPLERS OR IMPEDANCE PLANES
C             (CAN BE LEFT BLANK IF IZCASE = 0).
C     IDEV    IS A CODE FOR ADDITONAL PLOTTED DATA FOR THE DEVELOPMENT
C             OF COUPLERS.  IF IDEV IS NON-ZERO, IT WILL PLOT THE
C             INDIVIDUAL RESPONSE OF ALL TANDEM COUPLERS OF THE SOLUTION
C             ON SEPARATE GRAPHS. IF IDEV=0, NO DATA  IS GIVEN FOR THE
C             INDIVIDUAL COUPLERS OF THE TANDEM COUPLER SOLUTION.
C     ITABLE  IS A STARTING DATA CODE.  IF NON-ZERO IT SIGNIFIES THAT
C             THE DATA FOR STARTING THE SOLUTION IS TAKEN FROM
C             CHEBYSHEV ANTENNA TABLES.  LIST THE CENTER ELEMENT FIRST.
C             ETC., AND NORMALIZE FIRST (CENTER) VALUE TO 1.0. IF
C             ITABLE=0, THE STARTING DATA IS NOT TAKEN FROM ANTENNA
C             TABLES.
C     ZMIN    IS THE MINIMUM DESIRED EVEN MODE IMPEDANCE OF ANY COUPLED
C             SECTION IN A TANDEM COUPLER (OTHER THAN THE FIRST ONE).
C             IF ZMIN = 0 ON THE DATA CARD, THE PROGRAM FIXES ZMIN=1.001.
C     TRIMZ   IS A CODE FOR ARRANGING THE TANDEM COUPLERS. IF TRIMZ= 0,
C             THEN ALL INPUT TANDEM COUPLERS, PROVIDING THEY ARE SINGLE
C             SECTION COUPLERS, ARE MADE EQUAL. IF TRIMZ IS NONZERO,
C             NO ATTEMPT IS MADE TO TRY TO FIND EQUAL SINGLE SECTION
C             COUPLERS IN THE SOLUTION.
C     XPRINT  IS A CODE FOR OBTAINING THE PERFORMANCE DATA OF THE
C             DEVICE IN PRINTED FORM. IF NON-ZERO, THE PERFOR-
C             MANCE PER ITERATION WILL BE PRINTED.
C     SPEED   IS A CODE THAT CONTROLS  THE INTENSITY OF ERROR
C             CORRECTION. IF LEFT BLANK (I.E. ZERO) , THE ERROR
C             CORRCTION WILL BE WHAT THE THEORY DICTATES. BY
C             THIS CODE, RANGING BETWEEN LIMITS OF 0.1 TO 1.5,
C             THE NORMAL ERROR CORRECTION CAN BE ATTENUATED (BY
C             SETTING  SPEED  LESS THAN 1.0) OR AMPLIFIED (BY
C             SETTING  SPEED  GREATER THAN 1.0).
C
C     INUM    IS THE NUMBER OF IMPEDANCE VALUES IN THE SUCCEEDING TANDEM
C             COUPLER (ALSO EQUALS NU(IPLANE) WHERE IPLANE IS THE I(TH)
C             PLANE OF IMPEDANCES).
C     GAMMA   (1,J) IS THE J(TH) REFLECTON COEFFICIENT VALUE.
C
C
C     SAMPLE DATA CARDS
C
C     TYPE 1
C     IF THE DATA IS FROM CHEBYCHEV ANTENNA TABLES, THEN-
C
C     1ST DATA CARD - K, N, 0, ITEMAX, DELTA, UO, TOL, ZMAX, BW, 0
C             ACCORDING (ABBREVIATED ACC.) TO FORMAT (2I2, 2I3, 6F10.5)
C     2ND DATA CARD - 0, 0, IDEV, ., ZMIN, TRIMZ, .XPRINT,SPEED
C             ACC. TO FORMAT (2I2, 2I3, 6F10.5)
C     3RD DATA CARD - CHEBY(1)...CHEBY(N) ACC. TO FORMAT (7F10.5)
C         WHERE CHEBY(1) IS THE CENTER ELEMENT OF THE ANTENNA, AND
C         CHEBY(N) IS THE END ELEMENT OF THE ARRAY.
```

```
C     TYPE 2
C     IF THE DATA IS IN TERMS OF REFLECTION COEFFICIENTS, THEN-
C
C     1ST DATA CARD - K, N, 0, ITEMAX, DELTA, UO, TOL, ZMAX, BW, 0
C           ACC. TO FORMAT (2I2, 2I3, 6F10.5)
C     2ND DATA CARD - 0, 0, IDEV, 0, ZMIN, TRIMZ, ,XPRINT,SPEED
C           ACC. TO FORMAT (2I2, 2I3, 6F10.5)
C     3RD DATA CARD - GAMMA(1)...GAMMA(N) ACC. TO FORMAT (7F10.5)
C         WHERE GAMMA(1)  IS THE REFLECTION COEFFICIENT FOR THE
C         CENTER SECTION,  GAMMA(N) FOR THE END SECTION.
C
C
C
C     TYPE 3
C     IF THE DATA IS IN TERMS OF EVEN MODE IMPEDANCES, THEN-
C
C     1ST DATA CARD - K, N, 0, ITEMAX, DELTA, UO, TOL, ZMAX, BW, 0
C           ACC. TO FORMAT (2I2, 2I3, 6F10.5)
C     2ND DATA CARD - 1, N, IDEV, 0, ZMIN, TRIMZ, ,XPRINT,SPEED
C           ACC. TO FORMAT (2I2, 2I3, 6F10.5)
C     3RD DATA CARD - NU(1) ACC. TO FORMAT (I2)
C     4(TH) DATA CARD - Z, (Z(1,1)...Z(1,NU(1)) ACC. TO FORMAT
C           (7F10.5)
C     5(TH) DATA CARD - NU(2) ACC. TO FORMAT (I2)
C     6(TH) DATA CARD - Z(2,1)...Z(2,NU(2)) ACC. TO FORMAT (7F10.5)
C     .
C     .
C     .
C     (2N+2)(TH) DATA CARD - NU(N) ACC. TO FORMAT (2I2)
C     (2N+3)(TH) DATA CARD - Z(N,1)...Z(N,NU(N)) ACC. TO FORMAT (7F10.5)
C
C
C
C     TYPE 4
C     IF A PRECEEDING FINAL SOLUTION BECOMES THE STARTING DATA OF A
C           NEW PROBLEM, (AS IF ZMAX IS THE ONLY CHANGE), THEN-
C
C     1ST DATA CARD - K, N, 0, ITEMAX, DELTA, UO, TOL, ZMAX, BW, 1.
C           ACC. TO FORMAT (2I2, 2I3, 6F10.5)
C     2ND DATA CARD - 0, 0, IDEV, 0, ZMIN, TRIMZ, ,XPRINT,SPEED
C           ACC. TO FORMAT (2I2, 2I3, 6F10.5)
C
C
C
C     THE LAST DATA CARD (REQUIRED) - 0, 0, 1 ACC. TO FORMAT (2I2, 2I3)
C
C
C
      CALL SCOUTV(1,15)
       EXTERNAL TABLIV
      CALL RITSTV(16,26,TABLIV)
      CALL MAXFRM(500)
      DIMENSION  UPPR(8),BOTT(9),SIDE(9),DAY  (2),FLUNK(2),TOUGH(2)
      DIMENSION ALFA(2000),ALPHA( 500),TD( 500),VAL(50),PEAK(50)
     C,Z(30),  C(10,30),A(4,4),B(4,4),GAM(10,30),NMAX(30),TT(99 )
     C,UB(30), BI(50),UB(200) ,DGAM(30), THET(30), DU(30), XUB(30)
      DIMENSION NU(30) , ANGL(30),ANG(30), DUB(30),DB(30),GAMMA(3,30)
     C,AIBI(50), AGAM(3,30), BETA(300), CHEBY(25), SSI(25) ,YTOX(4)
       EQUIVALENCE( GAMMA,AGAM)
    1 FORMAT ( 2F10.5, 1F10.3, 6F10.5)
    2 FORMAT(7F10.5)
    3 FORMAT(2I2,2I3, 6F10.5)
    6 FORMAT(9A8)
    7 FORMAT(8A8)
    9 FORMAT(2A6)
   71 FORMAT(6X2HN=,I2,6X9HCOUPLING=,
     2 F8.4,4H DB  , 6X10HBANDWIDTH=,F8.3, 3XF8.3)
   72 FORMAT (1H/)
   73 FORMAT(6X2HN=,I2,6X12HPHASE SHIFT=,
     C F8.2, 9H DEGREES ,6X10HBANDWIDTH=, F8.3, 3XF8.3)
   74 FORMAT(10X8HRIPPLE= ,F8.4,5H   DB,8X10HTOLERANCE=,F8.4)
   75 FORMAT( 1H )
   76 FORMAT( 5X3HRL=,F8.3,7X,
     Z          9HRIPPLE=  ,F8.2,9H  DEGREES,8X10HTOLERANCE=,F8.4)
   78 FORMAT (5H NU(,I2,3H )=,I3          )
   80 FORMAT (1H1)
   81 FORMAT(9H UO =,F8.4, 4X4HBW =,F6.3,4X6HZMAX =,F8.5,
     2 4X,1HTOLERANCE= ,F8.5,
     C5X,38HTHE MAX. ALLOWABLE ITERATION(S) ARE = , I2 )
   83 FORMAT(5X,8HGAMMA(1,,I2, 5H  ) = ,F8.5)
   85 FORMAT(3H Z(,I2,1H,,I2,3H )=,F8.5,10X7HGAMMA (,I2,1H,,I2,3H )=,
     CF8.5, 10X 11H COUPLING =,F8.5)
   86 FORMAT(48H THE DESIGN DOES MEET THE SPECIFICATIONS, AFTER , I2
     1, 13H  ITERATIONS )
   89 FORMAT(5H VAL(,I2,3H)= ,F10.5)
   90 FORMAT(6H PEAK(,I2, 4H) = , F10.5)
   91 FORMAT( 4X5HDIFF.,4X7HRIPPLE,.2X,8HABSOLUTE,4X6HTHETA,
     C2X10HBANDWIDTH     )
   92 FORMAT(1X10HPHASE, DEG,4X3HDEG,4X10HPHASE, DEG,3X3HDEG,6X5HRATIO)
   93  FORMAT(1X/4X5HALPHA, 4X6HRIPPLE, 5X5HTHETA, 3X8HCOUPLING,
     C 3X6HRIPPLE, 3X9HBANDWIDTH    )
   95 FORMAT(/1X9H(DEGREES),2X9H(DEGREES), 2X9H(DEGREES), 3X4H(DB),
     C6X 4H(DB), 4X6HRATIO ,// )
   96 FORMAT (45X8H EXIT BY , I2 )
   97 FORMAT(3H Z(,I2,4H) = ,F8.5,10XI2)
   98 FORMAT (23H THE ERROR COEFFICIENT ,I2, 16H IS OSCILLATING, ,
     C 10H APPLY FIX ,I2)
   99 FORMAT ( 5X51HTHE DESIGN DOES NOT MEET THE SPECIFICATIONS -- FAIL)
  101 FORMAT ( 5X, 28HCAUTIOUS ERROR CORRECTION ( , F5.3 , 2HX))
  102 FORMAT ( 5X, 27H  NORMAL ERROR CORRECTION   )
  103 FORMAT ( 5X,28HEXCESSIVE ERROR CORRECTION ( , F5.3 , 2HX))
  105 FORMAT (/5X, 38HEXIT 1  IMPEDANCES ARE LESS THAN 1.0      ,
     C/5X49HEXIT 2  TOO MANY PEAKS/VALLEYS IN RESPONSE CURVE   ,
     C/5X49HEXIT 3  TOO FEW PEAKS/VALLEYS FOR ERROR ANALYSIS   ,
     C/5X48HEXIT 4  DESIGN OF PHASE SHIFTER NOW COMPLETED      ,
     C/5X48HEXIT 5  DESIGN OF COUPLER NOW COMPLETED            ,
     C/5X56HEXIT 6  DESIGN OF COUPLER USED MAX. ALLOWABLE ITERATIONS    ,
     C/5X59HEXIT 7  DESIGN OF PHASE SHIFTER USED MAX. ALLOW. ITERATIONS,
     C/5X53HEXIT 8  A PEAK AND VALLEY ARE BEYOND BANDWIDTH EDGE  )
      WRITE(16,80 )
      WRITE (6,105)
      RAD = 57.2957795
      READ ( 5,9) TOUGH
      READ (5,9) FLUNK
```

```
      READ (5,7) UPPR
      READ (5,6) BOTT
      READ (5,6) SIDE
      KRUN = 0
      NPAGE=0
      IZERO = 0
      IONE = 1
      ITWO = 2
      ITHREE = 3
      IFOUR = 4
      IFIVE = 5
      ISIX = 6
      ISEVEN = 7
      IEIGHT = 8
      ININE = 9
      ITEN = 10
      CALL DATE(DAY)
      WRITE (7,9) DAY
   20 READ (5,5)  K,N, NEND, ITEMAX, DELTA,UO,TOL,ZMAX,BW,CONT
      THBW = 180./(BW+1.)
      CALL TABLC(C,NU,NMAX,K,N,UO,BW, PERF ,TOLER,RL,DAY  ,KRUN,NEND)
      KRUN = KRUN + 1
      IF (NEND.GT.0) GO TO 595
      JRUN=0
      IRUN = 0
      ISCORE=0
      INSTBL = 0
      SCR1=0.
      KAX=K
      WRITE(6,80)
      WRITE(6,81) UO,BW, ZMAX, TOL, ITEMAX
      READ (5,5) IZCASE, M, IDEV ,ITABLE ,ZMIN,TRIMZ, XPRINT
     C , SPEED
      IF (SPEED. LE. .1) SPEED = 1.
      IF (SPEED. GT.1.5) SPEED = 1.
      IF(ZMIN.LE.0.) ZMIN=1.001
      IF(ITABLE) 35,35,27
C     DATA IN TERMS OF CHEBYCHEV ANTENNA DISTRIBUTIONS, ENDS AT 32
   27 READ (5,2)  ( CHEBY(I),I=1,N)
      IF(K.GT.0) GO TO 30
      SNUM=SIN(UO/RAD)*.5
      SSUM=0
      DO 28 I=1,N
      SSI(I)=(-1.)**(I-1)* CHEBY(I)/FLOAT(2*I-1)
   28 SSUM=SSUM+SSI(I)
      SNUM=SNUM/SSUM
      DO 29 I=1,N
   29 AGAM(1,I)=ABS(SSI(I))*SN...
      GO TO 60
   30 CONTINUE
      SNUM = 0.
      DO 31 I=1,N
      SSI(I) = CHEBY (I)/FLOAT(I)
      SUMPRO = SIN(THBW/RAD * FLOAT(I)) *SSI(I)
      SNUM= SNUM+ SUMPRO
   31 CONTINUE
      DO 32 I=1,N
   32 GAMMA(1,1) = SSI(I)*(UO/RAD*0.5/SNUM)
      GO TO 60
   35 CONTINUE
C     DATA IN TERMS OF    EVEN MODE IMPEDANCES, ENDS AT 55
   40 IF (IZCASE) 55,55,43
   43 IPLANE = 0
      DO 45 ITIMES = 1,M
      READ (5,5) INUX
      IPLANE = IPLANE + 1
       NU(IPLANE) = INUX
      READ (5,2) ( C(IPLANE,I) , I=1,INUX )
       WRITE (6,2) (C(IPLANE, I) , I=1,INUX)
   45 CONTINUE
      I=0
      DO 49 IPL =1,IPLANE
      KNUU =  NU(IPL) +1
      C(IPL, KNUU) = 1.
      DO 47 INIT = 1,N
      GAM (IPL,INIT) = 0.
   47 CONTINUE
      KNU = NU(IPL)
      DO 49 NNU =1,KNU
      JNU = KNU+1-NNU
      JJNU = JNU +1
      GAM(IPL, JNU) = (C(IPL,JNU) - C(IPL,JJNU))/(C(IPL,JNU)+C(IPL,JJNU)
     C)
C     WRITE (6,2) GAM(IPL, JNU)
   49 CONTINUE
      N = NU(1)
      DO 50 IKS=1,N
      AGAM(1,IKS) = 0.
      DO 50 IPL=1,IPLANE
      AGAM(1,IKS) = GAM(IPL,IKS) + AGAM(1,IKS)
   50 CONTINUE
      GO TO 60
   55 IF (CONT) 55,55,60
C     PRESENT INPUT DATA FROM PRECEEDING SOLUTION
   55 READ(5,2) (GAMMA(1,I) , I=1,N)
   60 DO 61 I=1,N
      WRITE (6,83)I,AGAM(1,I)
      GAM(1,I) = AGAM(1,I)
      TT(I) = GAM(1,I)
   61 CONTINUE
   62 CONTINUE
      JL = N
      L=1
      M = 0
      JSTOP=0
      NTOT=0
      ANGLE=(UO/90.0)
      M=1
      I=1
      NU(1)=N
C     WRITE (6,78) 1,NU(1)
      C(1,N+1)=1.
```

```
  122 C(I,N  )=(1.+GAM(I,N  ))/(1.-GAM(I,N  ))*C(I,N+1)
      IF(C(I,N)-ZMAX) 123,123,124
  123 N=N-1
      IF(N  ) 140,140,122
  124 NMAX(I)=N
      J=N
  125 C(N,J)=ZMAX
      IF(J-1)130,130,127
  127 GAM(N,J-1)=0.
      J=J-1
      IF(J) 130,130,125
  130 N=NMAX(I)
      J=N
      N=N+1
      GAMG=(ZMAX-C(N-1,J+1))/(ZMAX+C(N-1,J+1))
      GAM(N,J)=GAM(N-1,J)-GAMG
  131 J=J-1
      IF(J) 135,135,133
  133 CONTINUE
      GAM(K,J)=TT(J)
      IF(J-1) 135,135,131
  135 CONTINUE
      JG=N-1
      I=I+1
      NU(I)=N
C     WRITE (6,78) I,NU(I)
      C(I,N+1)=1.
      DO 139 L=1,JL
      VOL=(C(JG,L)**2-1.)/(C(JG,L)**2+1.)
      IF(L-N) 139,137,139
  137 GAM(JG,L) = GAMG
  139 WRITE (6,85) JG,L, C(JG,L),JG,L,GAM(JG,L) ,VOL
      JL=N
      GO TO 122
  140 DO 141 K=1,JL
      VOL=(C( I,K)**2-1.)/(C( I,K)**2+1.)
  141 WRITE (6,85) I,K,C(I,K) , I,K,GAM(I,K),VOL
      N=I
      NMAX = I
      N = NU(1)
      IF( TRIMZ.NE.0.) GO TO 185
      IF (N-2) 150,145,145
  145 CONTINUE
      CALL ZTRIM(C,NU, NMAX, ZMIN )
      N = NMAX
      DO 147 ILMX = 2,N
      ILMYX = NU(ILMX) + 1
      DO 147 ILMY = ILMYX, N
      C(ILMX, ILMY) = 0.
  147 CONTINUE
  150 CONTINUE
      IF (C(N,1) - 1.01) 185,185,160
  160 IF ( C(N,2)) 163,163,185
  163 GAMX = 0.
      L = 2
      IF ( C(N-1,2)) 165,165,165
  165 IF (C(N-2,2)) 170,170,175
  170 L=3
  175 DO 177 IL = 1,L
      IGAM = N-IL+1
      GAMX = GAMX+GAM(IGAM,1)
  177 CONTINUE
      GAMX = GAMX/ FLOAT(L)
      CIX = (1.+GAMX)/(1.-GAMX)
      DO 180 IL=1,L
      IGAM = N-IL+1
      GAM ( IGAM ,1) = GAMX
      IKONST = 1
      C( IGAM ,1) = CIX
      VOL=(CIX**2-1.)/(CIX**2+1.)
      WRITE (6,85) IGAM, IKONST,C(IGAM, 1) , IGAM, IKONST,GAM(IGAM,1),
     Z     VOL
  180 CONTINUE
  185 CONTINUE
      CALL ZTRIM(C,NU, NMAX, ZMIN )
      L=1
      I=0
      IPLANE = 0
      J = 0
      N = NMAX
C     WRITE (6,80)
  200 CONTINUE
      K=KAX
      IPLANE = IPLANE + 1
      N = NU(IPLANE)
      NTOT=NTOT+N
      FAIL = 0.
      DO 203 I=1, N
      Z(I) = C(IPLANE,I )
      IF(Z(I).LE.1.) FAIL = 10.
C     WRITE (6,97) I, Z(I) ,IPLANE
  203 CONTINUE
      IF(FAIL.LE.0.) GO TO 204
C     THIS IS EXIT 1
      WRITE ( 6,96 ) IONE
      GO TO 20
  204 ADX=0.
      RZX=0.
      LKO = 1
      THETA = THBW
  205 CONTINUE
  213 THETAR=THETA/57.2957795
      TRZX=RZX
      CO  =COS (THETAR)
      SO  =SIN (THETAR)
C     START CALCULATION OF COUPLER (OR PHASE SHIFTER) RESPONSE
      IF (K) 215,215,216
  215 A(1,1)=CO
      A(2,2)=CO
      A(1,2)=SO *Z(1)
      A(2,1)=SO *(1./Z(1))
      J=2
```

```
      GO TO 217
  216 HTH=THETAR/2.
      A(1,1)=COS (HTH)
      A(2,1)=(1./Z(1))*SIN (HTH)
      A(2,2)=A(1,1)
      A(1,2)=Z(1)*SIN (HTH)
      J=2
  217 IF(N-J) 223,220,220
  220 B(1,1)=A(1,1)*CO +(-1.)*Z(J)*SO *A(2,1)
      B(1,2)=CO *A(1,2)+Z(J)*SO *A(2,2)
      B(2,1)=(1./Z(J))*SO *A(1,1)+CO *A(2,1)
      B(2,2)=((-1.)/Z(J))*SO *A(1,2)+A(2,2)*CO
      A(1,1)=B(1,1)
      A(1,2)=B(1,2)
      A(2,1)=B(2,1)
      A(2,2)=B(2,2)
      J=J+1
      GO TO 217
  223 IF(K)225,225,224
  224 ALFA(L)=ATAN (A(1,1)*A(1,2)-A(2,1)*A(2,2))
      IF ( LKO - 1 ) 2242,2242,2244
 2242 THETA = DELTA
 2244 L=L+1
      LKO = LKO + 1
      THETA = THETA + DELTA
      IF(THETA-90.) 213,213,2246
 2246 IF(JSTOP) 2248,2248,267
 2248 JSTOP=L-1
      GO TO 267
  225 RZX=A(2,1)/A(1,1)
      IF(RZX-TRZX )227,230,230
  227 ADX = ADX+360.
  230 ALFA(L)=2.*RAD*ATAN(RZX)+ADX
      IF ( LKO -1 ) 233,233,235
  233 THETA = DELTA
      RZX = 0.
  235 L=L+1
      LKO = LKO + 1
      THETA = THETA + DELTA
      IF(THETA-90.) 213,213,236
  236 IF(JSTOP) 237,237,240
  237 JSTOP=L-1
  240 CONTINUE
      M=M-1
      IF(M) 243,243,200
  243 CONTINUE
      THETA = THBW
      L=L-1
      JK=JSTOP
       IF ( L-JSTOP )250,250,248
  248 DO 247 NN = 1,JSTOP
      JK=JK+1
      DO 247 NN1=JK,L,JSTOP
  247 ALFA(NN)=ALFA(NN)+ALFA(NN1)
  250 CONTINUE
      IF(XPRINT. LE .0.) GO TO 251
      WRITE (6,91)
      WRITE (6,91)
  251 WRITE (6,72)
      DO 255  LK=1,JSTOP
      UX=(FLOAT(2*NTOT)+ANGLE)*THETA
      RL=UX/360.
      U=UX-ALFA(LK)
      ALPHA(LK) = U
      IF (U.LT. 0.) ALPHA(LK) = ALPHA(LK) + 360.
       TD(LK) = THETA
      RIPO = UO -ALPHA(LK)
      ABW=(180. - THETA) /THETA
      IF(XPRINT. LE .0.) GO TO 252
      WRITE (6,1) ALPHA(LK),RIPO, ALFA(LK), THETA, ABW,DOTS, U
  252 IF (LK - 1 ) 253,253,255
  253 THBW = THETA
      UBW=ALPHA(LK)
      THETA = DELTA
  254 THETA=THETA+DELTA
C     END OF PHASE SHIFTER
      GO TO 295
C     CONTINUE OF COUPLER RESPONSE CALCULATION - END AT 335
  267 CONTINUE
      M=M-1
      IF(M) 270,270,200
  270 CONTINUE
      L=L-1
  273 THETA = THBW
      JK=JSTOP
      IF ( L-JSTOP) 285,285,275
  275 CONTINUE
      IF (IDEV) 283,283,277
  277 IF (IRUN- ITEMAX ) 283,280,280
  280 CONTINUE
      LBI = 0
      DO 282 JLKX= 1, MMAX
      TD(1) = 0.
      JKX = 1
      DO 281 JLK = JKX, JSTOP
      LBI = LBI+1
      BETA( JLK) = 20. *ALOG10(ABS(SIN(ALFA(LBI))))
      TD(JLK)=DELTA*FLOAT(JLK)
  281 CONTINUE
      JSTOPX=JSTOP-1
      CALL AICRT 3(0,0,TD(2), BETA (2), JSTOPX,1.2, 1,44,
     CUPPR, BOTT, SIDE, 1,1, 16., 16., 1, XL,XU, 1, YL,YU)
  282 CONTINUE
      IDEV = 0
  283 CONTINUE
      DO 284 NN=1, JSTOP
      JK=JK+1
      DO 284 NN1 =JK,L,JSTOP
  284 ALFA(NN)=ALFA(NN)+ALFA(NN1)
  285 CONTINUE
      IF(XPRINT. LE .0.) GO TO 286
      WRITE(6,93)
```

```
      WRITE(6,99)
  286 RIPX = 20.* ALOG10(SIN(UO/57.2957795))
      DO 294   LK=1,JSTOP
      ALPHA(LK)=ALFA(LK)*RAD
      TD(LK) = THETA
      RIP1     = UO -ALPHA(LK)
      ABW=(180. - THETA) /THETA
      IF(ALFA(LK))     289,289,290
  289 TENLOG=-0.
      GO TO 291
  290 TENLOG = 20.*ALOG10(SIN(ALFA(LK)))
      RIPDB = RIPX - TENLOG
  291 IF(XPRINT. LE .0.) GO TO 292
      WRITE(6,1)ALPHA(LK),RIP1     ,THETA,TENLOG,RIPDB,ABW
  292 IF (LK-1 ) 293,293,294
  293 THBW = THETA
      UBW =ALPHA(LK)
      THETA = DELTA
  294 THETA=THETA+DELTA
C     START PHASE SHIFTER AND CONTINUE COUPLER
  295 MGO = 1
      NPAGE=NPAGE+1
      ZPG = NPAGE
C     IF(XPRINT. LE .0.) GO TO 296
C     WRITE (6,80)
  296 N=NU(1)
      KGO = 2
      VAL(1) = ALPHA(1)
      JGO = JSTOP - 2
      KOUNT = 1
      DO 313 I=2,JGO
      IF ((ALPHA(I) - ALPHA(I+1)) * (ALPHA(I+1)-ALPHA (I+2)))  300,300,
     1 310
  300 UB(KOUNT) = ALPHA(I+1)
      THET(KOUNT) = TD(I+1)
      KOUNT = KOUNT + 1
      IF(ALPHA(I) - ALPHA(I+1)) 307,303,305
  303 IF(ALPHA(I+1) - ALPHA(I+2)) 305,305,307
  305 VAL(KGO) = ALPHA(I+1)
      KGO = KGO +1
      GO TO 310
  307 PEAK(MGO) = ALPHA(I+1)
      MGO = MGO+1
  310 CONTINUE
  313 CONTINUE
      IF(KAX.LE.0) GO TO 320
      UB(KOUNT) = ALPHA(JSTOP)
      THET(KOUNT) = 90.
      IF (ALPHA(JSTOP-1) - ALPHA(JSTOP)) 317,317,315
  315 VAL(KGO) = ALPHA(JSTOP)
      KGO = KGO+1
      GO TO 320
  317 PEAK(MGO) = ALPHA(JSTOP)
      MGO = MGO+1
  320 IF(KAX.LE.0) KOUNT = KOUNT - 1
      K1X = KGO -1
      DO 330 IKX = 1,K1X
      WRITE (6,89) IKX,VAL(IKX)
  330 CONTINUE
      M1X = MGO-1
      DO 331 IMX =1,M1X
      WRITE(6,90) IMX,PEAK(IMX)
  331 CONTINUE
      CAUTN = 0.
      IF(NU(1) .EQ. 2 )   GO TO 333
      IF((K1X-1 + M1X) - NU(1)) 332,333,3310
 3310 WRITE ( 6,96 ) ITWO
C     THIS IS EXIT 2
      GO TO 20
  332 CAUTN = 10.
  333 CONTINUE
      IF(IRUN) 334,334,3340
  334 CAUTN=5.
C     WRITE (6,5) IZERO,IRUN
 3340 IRUN=IRUN+1
      JRUN=JRUN+1
      JSTOPX=JSTOP-1
      K = KAX
  335 IF(K) 337,337,417
  337 IF(K1X.GE.1) GO TO 338
      IF(M1X.GE.1) GO TO 338
      WRITE ( 6,96 ) ITHREE
C     THIS IS EXIT 3
      GO TO 20
  338 VMIN = XMN(K1X,VAL)
      VMAX = XMX(K1X,VAL)
      PMIN = XMN(M1X,PEAK)
      PMAX = XMX(M1X,PEAK)
      NPOFF=2*N-1
      PERF = (PMAX - VMIN + PMIN - VMAX )/4.
      YTOX(1) = ABS( VMIN + PERF - UO )
      YTOX(2) = ABS( VMAX + PERF - UO )
      YTOX(3) = ABS( PMAX - PERF - UO )
      YTOX(4) = ABS( PMIN - PERF - UO )
      YTOL = XMX(4,YTOX)
      TOLER = YTOL
  350 IF (ABS(VMAX- VMIN) - TOL*PERF ) 353,353,365
  353 IF(ABS (PMAX - PMIN) - TOL*PERF ) 355,355,365
  355 IF ( ABS((PMAX-UO)-(UO- VMIN)) - (2.*TOL*PERF )) 357,357,365
  357 WRITE(6,88) IRUN
      CALLPLOT(TD,ALPHA,JSTOP,VAL,K1X,PEAK,M1X,C,NU,MMAX,K,BW,UO,
     Z     ZPG,DAY  )
      I1000 = IPLANE
      IPLANE = 0
      WRITE(7,75)
      WRITE(7,73) N     ,UO,BW ,C(1,1)
      WRITE(7,76) RL,PERF,YTOL
      WRITE (7,5) K,N,NEND , ITEMAX, DELTA,UO,TOL,ZMAX,BW
      WRITE(7,2) (AGAM(1,I) ,I=1,N)
      WRITE(7,5) MMAX
      DO 360 ITIMES =1,MMAX
      IPLANE = IPLANE +1
```

```
      INUK5  = NU(IPLANE)
      WRITE(7,5) INUK5
      WRITE(7,2)   (C(IPLANE,I) , I=1,INUK5)
  360 CONTINUE
      IPLANE = I1000
      WRITE ( 6,96 ) IFOUR
C     THIS IS EXIT 4
      GO TO 20
  365 CONTINUE
C     START OF ERROR CORRECTION FOR PHASE SHIFTERS
      DU(1) = U0 - UBW
      D@(1)=DU(1)
  400 DU(1)=SQRT(DU(1)**2)
      ANG(1) = THBW
      DO 403 I=1,KOUNT
      DU(I+1) = U0 - UB(I)
       D@(I+1)=DU(I+1)
      DU(I+1)=SQRT(DU(I+1)**2)
      ANG(I+1) = THET(I)
  403 CONTINUE
      DUA=0.
      IKO = KOUNT + 1
      DO 405  I=1,IKO
  405 DUA = DUA    + DU(I)
      DUAVE = DUA/ FLOAT(N+1)
      DUAVEX = DUAVE
      DO 407 I=1,IKO
  407 WRITE(6,2) D@(I),DUAVE
      I=1
  410 DU@(I)=D@(I)-DUAVE
      IF(I-IKO) 413,457,457
  413 I=I+1
      DU@(I)= (D@(I)+DUAVE  )
      IF (I-IKO) 415,457,457
  415 I=I+1
      GO TO 410
  417 CONTINUE
      DU(1) = U0 - UBW
      D@(1)=DU(1)
      DU(1) = ABS(RIPX - 20.*ALOG10(SIN(UBW/RAD)))
      ANG(1) = THBW
      DO420 I=1,KOUNT
      DU(I+1) = U0 - UB(I)
       D@(I+1)=DU(I+1)
      DU(I+1) = ABS(RIPX -20.*ALOG10 (SIN(UB(I)/RAD)))
      ANG(I+1) = THET(I)
  420 CONTINUE
      DUA=0.
      IKO = KOUNT + 1
      DO 423 I=1,IKO
  423 DUA = DUA    + DU(I)
      DUAVE = DUA/ FLOAT(N+1)
      DUAVEX = 10.**((RIPX+DUAVE)/20.)
      DUAVEX =ABS(ATAN(DUAVEX/(SQRT(1.-DUAVEX**2)))-U0)
      DO425 I=1,IKO
  425 WRITE(6,2) DU(I),DUAVE
      RIPP = XMX(IKO,DU)
      RIPM = XMN(IKO,DU)
      PERF=(RIPP+RIPM)*.5
      YTOL=(RIPP-RIPM)*.5
      TOLER = YTOL
      NPOFF=2*N-1
      IF ((RIPP-RIPM) - TOL*DUAVE)427,427,435
  427 IF(IDEV . LE . 0) GO TO 428
      ITEMAX = IRUN
C  THIS WILL YIELD THE DEVELOPMENT DATA
      GO TO 60
  428 WRITE(6,88) IRUN
      WRITE (7,75)
      WRITE (7,75)
      U3 = U0
      CALLPLOT(TD,ALPHA,JSTOP,VAL,K1X,PEAK,M1X,C,NU,MMAX,K,BW,U0,
     Z    ZPG,DAY  )
      I1000 = IPLANE
      IPLANE = 0
      WRITE(7,71) NPOFF,RIPX,BW ,C(1,1)
      WRITE(7,74) PERF,YTOL
      WRITE(7,5) MMAX
      DO 433 ITIMES =1,MMAX
      IPLANE = IPLANE +1
      INUK5  = NU(IPLANE)
      WRITE(7,5) INUK5
      WRITE(7,2)   (C(IPLANE,I) , I=1,INUK5)
  433 CONTINUE
      WRITE (7,5) K,N,NEND , ITEMAX, DELTA,U0,TOL,ZMAX,BW
      WRITE(7,2) (AGAM(1,I) ,I=1,N)
      IPLANE = I1000
      WRITE ( 6,96 ) IFIVE
C     THIS IS EXIT 5
      GO TO 20
  435 I=1
      IF( IRUN- ITEMAX) 440,440,437
  437 CONTINUE
      WRITE (7,5) K,N,NEND , ITEMAX, DELTA,U0,TOL,ZMAX,BW
      WRITE (7,75)
      WRITE(7,2) (AGAM(1,I) ,I=1,N)
      CALLPLOT(TD,ALPHA,JSTOP,VAL,K1X,PEAK,M1X,C,NU,MMAX,K,BW,U0,
     Z    ZPG,DAY  )
      CALL PRINTV(12,FLUNK, 918,15)
      WRITE ( 6,99)
      WRITE ( 6,96 ) ISIX
C     THIS IS EXIT 6
      GO TO 20
  440 CONTINUE
  442 DUVV = 10. **((RIPX - DUAVE)/20.)
      DUAVEV = ABS(U0- ATAN(DUVV/SQRT(1.-(DUVV) **2))*RAD )
  443 DU@(I)=D@(I)-DUAVEV
C     WRITE (6,2) DUVV, DUAVEV, DU@(I)
      IF(I-IKO`445,460,460
  445 I=I+1
      DUPV = 10. **((RIPX + DUAVE)/20.)
      DUAVEP = ABS(U0- ATAN(DUPV/SQRT(1.-(DUPV) **2))*RAD )
```

```
      DUQ(I)= (DQ(I)+DUAVEP )
C     WRITE (6,2) DUPV, DUAVEP, DUQ(I)
  447 IF (I-IKO)450,460,460
  450 I= I+1
      GO TO 443
  457 CONTINUE
      IF(IRUN-ITEMAX) 459,458,458
  458 WRITE(7,75)
      WRITE (7,75)
      WRITE(7,99)
      WRITE (7,5) K,N,NEND , ITEMAX, DELTA,UO,TOL,ZMAX,BW
      WRITE (7,75)
      WRITE(7,2) (AGAM(1,1) ,I=1,N)
      CALLPLOT(ID,ALPHA,JSTOP,VAL,K1X,PEAK,M1X,C,NU,MMAX,K,BW,UO,
     Z     ZP6,DAY  )
      CALL PRINTV(12,FLUNK, 910,15)
      WRITE ( 6,99)
      WRITE ( 6,96 ) ISEVEN
C     THIS IS EXIT 7
      GO TO 4601
  459 CONTINUE
  460 IF(ANG(3).LE.0.) GO TO 461
      IF(ANG(1).LE.ANG(3)) GO TO 461
      WRITE ( 6,96 ) IEIGHT
C     THIS IS EXIT 8
 4601 GO TO 20
  461 IF(ANG(1)- ANG(2)) 463,463,462
  462 ANGL(2) = (ANG(1) + ANG(3))/2.
      XUQ(2) = DUQ(2)
      ANGL(1) = ANG(1)
      ANG(1)=0.
      XUQ(1) = DUQ(1)
      DUQ(1)=0.
      GO TO 464
  463 ANGL(1) = ANG(1)
      ANG(1)=0.
      ANGL(2) = ANG(2)
      ANG(2)= 0.
      XUQ(1)=DUQ(1)
      DUQ(1) = 0.
      XUQ(2)=DUQ(2)
      DUQ(2)=0.
  464 IF(2-IKO) 465,469,469
  465 DO 466 J=3,IKO
      ANGL(J)=ANG(J)
      ANG(J) = 0.
      XUQ(J)=DUQ(J)
      DUQ(J) = 0.
  466 CONTINUE
  469 IF(KAX.GT.0) GO TO 470
      IKO = IKO + 1
      XUQ (IKO) =  0.
      ANGL(IKO) = 90.
  470 IT=2
C     DO 471 I=1,IKO
C 471 WRITE(6,2) XUQ(I) ,ANGL(I)
      I=1
      UQ(1) = 0.
      THETA = 0.
      DSLO = (XUQ(1) / ANGL(1) )*DELTA
      UQ(1) = DSLO
      THETA = DELTA
  472 I= I+1
      UQ(I) = UQ(I-1) + DSLO
      THETA = THETA + DELTA
C     WRITE (6,2) UQ(I), THETA
      IF(THETA+DELTA-ANGL(1)) 472,472,473
  473 DSLO = (XUQ(IT) - XUQ(IT-1))/(ANGL(IT)-ANGL(IT-1))* DELTA
  474 I=I+1
      LJ(I)=UQ(I-1)+DSLO
      THETA = THETA + DELTA
C     WRITE (6,2) UQ(I), THETA
      IF (THETA - ANGL(IT)) 474,475,475
  475 CONTINUE
       IT=IT+1
      IF(IT-IKO) 473,473,495
  495 CONTINUE
      DTH=DELTA
      K = KAX
      N = NU(1)
      CALL COEF(UQ,   DTH,K,N,BI)
C     RESPONSE ERROR ANALYSIS COMPLETE
C     START IMPROVEMENT OF PREVIOUS SOLUTION
  502 KSET = 0
      I7=0
      ZEE=1.
      ZAW=1.
      KSET2 = 0
      IDX = 2-KAX
      NI = 2*N -K
      IBK=IDX
      DO 515 IB= IDX,NI,2
      BIBI(IB) = ABS(BI(IB))
      NI1 = 2*(N+1) -K
  515 CONTINUE
  520 BIMAX= BIBI( IDX)
      IBKD=IDX
      DO 525 JIPS=1,NI
      IPS=2*JIPS-KAX
      IF(BIMAX-BIBI(IPS)) 523,525,525
  523 BIMAX=BIBI(IPS)
      IBKD=IPS
  525 CONTINUE
      WRITE (6,5) IZERO,IBK
      IF (BIMAX- 0.8 * DUAVEX) 530,530,527
  527 CONTINUE
      CAUTN = 5.
  530 CONTINUE
  533 IF (K) 535,535,537
  535 I7=IBK/2
      IF(CAUTN. GT. 0.) GO TO 536
      ZAW = 1.
```

```
      CALL SCORE(IBK,BI(IBK), SCR1,ZAW,ZEE, ISCORE )
      GO TO 540
  536 ZAW = 0.5
      GO TO 540
  537 I7=(IBK+1)/2
      IF(CAUTN. GT. 0.) GO TO 539
      ZAW = 1.
      CALL SCORE(IBK,BI(IBK), SCR1,ZAW,ZEE, ISCORE )
      GO TO 540
  539 ZAW = 0.5
      GO TO 540
  540 NUB = NU(1)
      JTEST=0
      SPD = 1.
      CALL OSCIL(JRUN,AGAM,BI(IBK),IBK,NUB,JTEST,IRUN,ITEMAX)
      WRITE (6,5) IZERO, JTEST
      SPD =ZAW*ZEE*SPEED
      IF(JTEST) 542,542,578
  542 IF ((ZAW* ZEE) -1.) 5420,5421,5422
 5420 WRITE (6,101)  SPD
      GO TO 5423
 5421 WRITE (6,102)
      GO TO 5423
 5422 WRITE (6,103)  SPD
 5423 IF(XPRINT. LE .0.) GO TO 5424
      WRITE (6,60)
 5424 DO 575 I=1,NUB
       IF(K) 550,550,543
  543 KIK = 2*(I-1) + K
  545 DGAM(I)=BI(KIK)/RAD*ZAW*.5 *ZEE  *SPEED
      GO TO 570
  550 KIK=2*I
  565 DGAM(I)=BI(KIK)*ZAW/RAD *ZEE*SPEED
  570 AGAM(1,I) = + DGAM(I)+AGAM(1,I)
  575 CONTINUE
  578 CONTINUE
      IF(JTEST.LE.0) GO TO 580
      ITYP = 1
      JTINS = JTEST + INSTBL
      IF ( JTINS .GT.20 ) ITYP = 2
      IF ( INSTBL . GT .15 )  TRIMZ = 10.
C     IF ( INSTBL . EQ. 15) TOL = TOL*2.
      WRITE(7,75)
      WRITE (7,75)
      WRITE(7,99)
      WRITE ( 6,98 ) IBK, ITYP
      WRITE ( 7,98 ) IBK, ITYP
      WRITE (7,5) K,N,NEND , ITEMAX, DELTA,UO,TOL,ZMAX,BW
      WRITE (7,75)
      WRITE(7,2) (AGAM(1,I) ,I=1,N)
      CALLPLOT(TD,ALPHA,JSTOP,VAL,KIX,PEAK,MIX,C,NU,MMAX,K,BW,UO,
     Z     ZPG,DAY  )
      CALL PRINTV(12,TOUGH, 910, 15)
      INSTBL = 5+ INSTBL
  580 CONTINUE
      N= NU(1)

  590 GO TO 80
C
C
  595 WRITE ( 6,105)
      RETURN
C
C
      END
```

```
      SUBROUTINE ZTRIM(C,NU,MMAX,ZMIN)
C
C     THE PURPOSE OF THE ZTRIM SUBROUTINE IS TO LIMIT THE IMPEDANCE
C        VALUES TO SOME ZMIN OR HIGHER FOR THE INPUT END OF COUPLERS.
C
      DIMENSION C(10,30),NU(10),NUT(10)
      DO 10 IPL=2,MMAX
      NUX=NU(IPL)
      NUT(IPL)=0
      DO 10 I=1,NUX
      IF(C(IPL,I)-ZMIN) 5,10,10
    5 NU(IPL)=NU(IPL)-1
   10 CONTINUE
      IF(NU(MMAX)) 15,15,25
   15 MMAX=MMAX-1
   25 RETURN
      END



      FUNCTION XMX(N,XN )
C
C     FUNCTION XMX WILL FIND THE MAXIMUM VALUE IN THE XN ARRAY OF SIZE N
C
      DIMENSION XN(500)
  101 FORMAT ( 42H THE DIMENSION IN FUNCTION XMX IS EXCEEDED     )
      IF(N-500) 10,10,100
   10 XMX=XN(1)
      DO 1 I=1,N
      IF(XMX-XN(I)) 2,1,1
    2 XMX=XN(I)
    1 CONTINUE
      GO TO 200
  100 WRITE(6,101)
  200 RETURN
      END



      FUNCTION XMN(N,XN )
C
C     FUNCTION XMN WILL FIND THE MINIMUM VALUE IN THE XN ARRAY OF SIZE N
C
      DIMENSION XN(500)
  101 FORMAT ( 42H THE DIMENSION IN FUNCTION XMN IS EXCEEDED     )
      IF(N-500) 10,10,100
   10 XMN=XN(1)
      DO 1 I=1,N
      IF(XN(I)-XMN)2,1,1
    2 XMN=XN(I)
    1 CONTINUE
      GO TO 200
  100 WRITE(6,101)
  200 RETURN
      END
```

```
      SUBROUTINE COEF(UG,   DTH,K,N,BI)
C
C     THE PURPOSE OF THE COEF SUBROUTINE IS TO FIND THE FOURIER (SINE)
C        COEFFICIENTS OF THE ERROR CURVE (UG VERSUS THETA). THE THETA
C        ARRAY IS IMPLICIT --- FROM  0 TO 90 DEGREES IN EQUAL DTH
C        INCREMENTS.
C     BY SPECIAL CONSIDERATION OF SYMMETRY, THE NUMERICAL INTEGRATION,
C        USING SIMPSONS RULE, IS OVER  THETA OF 0 TO 90 DEGREES.
C
      DIMENSION BI(50),UG(200),YIK(200)
    1 FORMAT(3H BI, I2, 3H )=, F8.5)
      PI=3.14159265
      RAD = 180./PI
      IX = 0
      MM=0
      NI = 2*(N+1) -K
    2 KIK=2*IX+K
      TH=DTH
      RTH=TH/RAD
      IF ( KIK) 25,25,4
    4 XKIK=KIK
    6 MM=MM+1
      YIK(MM)=UG(MM)*SIN(XKIK*RTH)
      TH=TH+DTH
      RTH=TH/RAD
      IF(TH-90.000001) 6,6,8
    8 YO=0.
      DO 10 IM=1,MM,2
   10 YO=YO+YIK(IM)
      IF (-1. **MM)  12,12,13
   12 YO = YO - YIK(MM)/2.
      GO TO 14
   13 YIK(MM) = YIK(MM)/2.
   14 YE = 0.
      DO 16 IM=2,MM,2
   16 YE=YE+YIK(IM)
      BI(KIK) = 2./PI *(8.*YO +4.*YE)*DTH/(3.*RAD)
      WRITE (6,1 ) KIK,BI(KIK)
      MM = 0
   25 IX=IX+1
      IF(KIK-NI) 2,27,27
   27 RETURN
      END
```

```
      SUBROUTINEPLOT(TD,ALPHA,JSTOP,VAL,KIX,PEAK,MIX,C,NU,MMAX,K,BW,UO,
     Z    ZPG,DATE )
C
C     THE PURPOSE OF THE  PLOT SUBROUTINE IS TO ---
C        1 PLOT THE RESPONSE FUNCTION ,LABELLING MAX AND MIN VALUES,
C        2 TITLE THE PLOT IN LARGE AND CENTERED LETTERS,
C        3 DISPLAY CLEARLY THE COUPLER/PHASE SHIFTER IMPEDANCE (AND
C            VOLTAGE COUPLING ) VALUES ,   AND
C        4 DATE THE DATA
C
C     TD     = THETA,NORMALIZED FREQUENCY (IN DEGREES).
C     ALPHA  = RESPONCE FUNCTION (AN ARRAY) TO BE PLOTTED, WHICH
C              CONTAINS THE PEAKS(VALLEYS .
C     JSTOP  = SUBCRIPT OF THE LARGEST TD.
C     VAL    = RELATIVE MINIMUM VALUES (I.E. VALLEYS) OF ALPHA.
C     KIX    = SIZE OF VAL (ARRAY).
C     PEAK   = RELATIVE MAXIMUM VALUES (I.E. PEAKS) OF ALPHA.
C     MIX    = SIZE OF PEAK (ARRAY).
C     C      = THE TWO-DIMENSIONAL IMPEDANCE ARRAY.
C     NU     = NUMBER OF COLUMNS OF C ARRAY (I.E. THE NUMBER
C              OF COUPLED SECTIONS IN ANY ONE TANDEM COUPLER).
C     MMAX   = SIZE OF NU ARRAY.
C     K      = CODE OF THE DEVICE, I.E.
G             = 1, FOR THE COUPLER
C             = 0, FOR THE PHASE SHIFTER
C     BW     = BANDWIDTH
C     UO     = NOMINAL VALUE OF THE RESPONSE FUNCTION.
C     ZPG= PAGE NUMBER
C
      DIMENSION C(10,30),NU(30),TD(360),ALPHA(360),VAL(50),PEAK(50),
     Z    CA(360),JP(50),JV(50)
   41 FORMAT(40X,I5,2F15.5)
      U2=UO
      XR=90.
      XL = TD(1) -5.
      RD=3.14159/180.
      YT=XMX(MIX,PEAK)
      YB=XMN(KIX,VAL)
      IST=2
      DO 1 I=2,JSTOP
      IF(TD(I)-TD(I)) 9,9,1
    9 IST=I-1
      GO TO 2
    1 CONTINUE
    2 MM=0
      NN=0
C     THIS SECTION PREPARES ALPHA TO BE PLOTTED ACC. TO K=0 OR K=1.
C     ALSO FINDS SUBSCRIPTS OF ALPHA (PEAKS,VALLEYS) TO ENABLE LABELING
C     OF PEAK,VALLEY VALUES ON PLOT
      IF (K) 101,101,100
  100 CA(1)=20.*ALOG10(SIN(ALPHA(1)*RD))
      U2 = 20.*ALOG10(SIN(U2*RD))
      GO TO 103
  101 CA(1) = ALPHA(1)
  103 DO 8 I=IST,JSTOP
      IF(K)  105,105,107
  107 CA(I)=20.*ALOG10(SIN(ALPHA(I)*RD))
      GO TO 109
  105 CA(I) = ALPHA(I)
  109 DO 7 J=1,KIX
C     WRITE (6,41) J,ALPHA(I),VAL(J)
      IF(ALPHA(I)-VAL(J)) 7,6,7
    6 MM=MM+1
      JV(MM)=I
C     WRITE (6,41) I
      GO TO 8
    7 CONTINUE
    5 DO 4 J=1,MIX
C     WRITE (6,41) J,ALPHA(I),PEAK(J)
      IF(ALPHA(I)-PEAK(J)) 4,3,4
    3 NN=NN+1
      JP(NN)=I
C     WRITE (6,41) I
      GO TO 8
    4 CONTINUE
    8 CONTINUE
      IF(K) 200,200,201
  201 YT=20.*ALOG10(SIN(YT*RD))
      YB=20.*ALOG10(SIN(YB*RD))
      GO TO 203
  200 CONTINUE
  203 YB=AMIN1(YB,CA(IST))
       EXTERNAL TABLIV
      CALL CAMRAV(2)
      CALL RITSTV(18,26,TABLIV)
C     ESTABLISH GRID MARGINS,SPACING OF GRID LINES
      CALL SETMIV(60,30,340,50)
      CALL DXDYV(1,XL,XR,DX,N,I,NX,8.0,IR)
      CALL DXDYV(2,YB,YT,DY,M,J,NY,8.0,IR)
      YB=YB-DY
      YT=YT+DY
      CALL GRID1V(1,XL,XR,YB,YT,DX,DY,N,M,I,J,NX,NY)
C     PLOTS  TD VS COUPLING...TWICE FOR BRIGHTNESS
      DO 69 IO=1,2
      NXO=NXV(TD(IST))
       NYO=NYV(CA(IST))
      IS=IST+1
      DO 11 I=IS,JSTOP
      NX=NXV(TD(I))
      NY=NYV(CA(I))
      CALL LINEV(NXO,NYO,NX,NY)
      NXO=NX
      NYO=NY
   11 CONTINUE
   69 CONTINUE
C     PLOTS AVERAGE UO  (OVERLAY)
      WW=180./(BW+1.)
      NXO=NXV(WW)
      NYO = NYV(U2)
      NX = NXV(TD(JSTOP))
      NY  = NYV(U2)
```

```
      CALLLINEV( NXO,NYO,NX,NY)
      CALLLINEV( NXO,NYO,NX,NY)
      NN=NN+1
      JV(NN)=I
C     PLOTS VALLEY VALUES
      DO 25 I=1,NN
      N=JV(I)
      NX=NXV(TD(N))-24
      NY=NYV(CA(N))-12
   25 CALL LABLV(CA(N),NX,NY,7,2,3)
C      PLOTS PEAK VALUES
      DO 26 I=1,NN
      N=JP(I)
      NX=NXV(TD(N))-24
      NY=NYV(CA(N))+12
   26 CALL LABLV(CA(N),NX,NY,7,2,3)
      EXTERNAL RITE2V
C     LABELS PLOTS IN SMALL LETTERS,AND TITLE OF GRAPH(**TO 1.0 BW) IN
C             LARGE LETTERS USING WRITE 18, ACCORDING TO K=0 OR K=1
      CALL VOUTV(24,RITE2V)
      IF(K) 30,30,31
   30 CALL APRNTV(0,-14,34,34HDIFFERENTIAL PHASE SHIFT  DEGREES ,30,860)
      CALL VLCSTV(240,280)
      WRITE(18,46) BW
   46 FORMAT(1H ,F6.3,1X,30HTO 1.0 BANDWIDTH PHASE SHIFTER)
      GO TO 32
   31 CALL VLCSTV(287,280)
      WRITE(18,49) BW
   49 FORMAT(1H ,F6.3,1X,24HTO 1.0 BANDWIDTH COUPLER)
      CALL APRNTV(G,-14,13,13HCOUPLING  DB ,30,730)
   32 CALL PRINTV(15,15HTHETA (DEGREES),462,320)
      NQY=270
C     PLOTS IMPEDENCE (C) VALUES , DATE AND PAGE NUMBER
      DO 35 IMPX=1,MMAX
      NQX=25
      NQY=NQY-45
      NUU=NU(IMPX)
      DO 35 IMPY=1,NUU
      NQX=NQX+75
      CALL LABLV(C(IMPX,IMPY),NQX,NQY,7,2,1)
      NQYC=NQY-15
      COUP=(C(IMPX,IMPY)**2 -1.)/(C(IMPX,IMPY)**2+1.)
   35 CALL LABLV(COUP,NQX,NQYC,7,2,1)
      CALL PRINTV(12,DATE ,918,35)
      CALL LABLV(ZPG,950,25,3,2,3)
      RETURN
      END
```

```
      SUBROUTINE SCORE(IBKD, BMAX,    SCR1,ZAW,ZEE,ISCORE)
C
C     THE PURPOSE OF THE  SCORE SUBROUTINE IS TO EITHER AMPLIFY OF
C        DIMINISH THE ERROR CORECTION VALUE . AMPLIFY,WHEN IN TWO
C        CONSECUTIVE  ITERATION THE  ERROR COEFFICIENTS ARE STATIONARY,
C        AND DIMINISH, ON  THE FIRST ITERATION AND ANY OTHER IF THE
C        CORRECTION  IS EXTREMELY  GREAT.
C
      SCR2= BMAX
      IF(IBKD-ISCORE) 10,5,10
    5 CONTINUE
      IF(SCR2-SCR1) 1,4,3
    3 IF(SCR1-.8*SCR2)10,4,4
    4 ZAW=1.
      ZEE=1.5
      GO TO 10
    1 IF(SCR2-.8*SCR1) 10,4,4
   10 SCR1=SCR2
      ISCORE=IBKD
      RETURN
      END
```

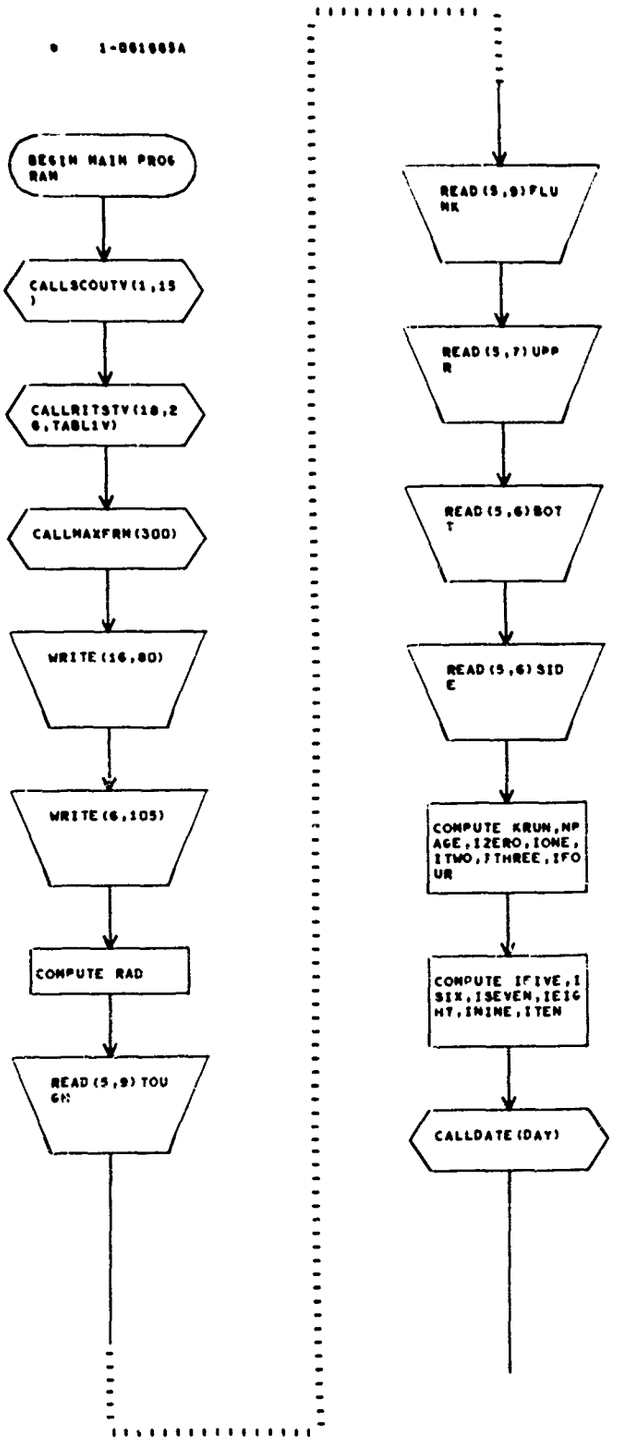
```
      SUBROUTINE OSCIL(JRUN,ATAU,BIMAX,IBK,NUB,JTEST,IRUN,ITEMAX)
C
C     THE PURPOSE OF THIS SUBROUTINE IS TO DETERMINE AND CORRECT
C           AN OSCILLATING ERROR CORRECTION PROCESS.
C
      DIMENSION ATAU(3,30),OLDTAU(2,30),BMX(2),IK(2),XTAU(1,30)
  100 FORMAT ( 9X,I15,3F10.5)
      IF(JRUN-2)  4,4,5
    4 GOTO (1,2), JRUN
    1 DO 3 I=1,NUB
    3 OLDTAU(1,I)=ATAU(1,I)
      BMX(1)=BIMAX
      IK(1)=IBK
      MID = 0
      LOW = 0
      RETURN
    2 DO 11 I=1,NUB
   11 OLDTAU(2,I)=ATAU(1,I)
      BMX(2)=BIMAX
      IK(2)=IBK
      RETURN
    5 IF(LOW.GT.0) GO TO 17
      IF(IBK-IK(1)) 6,8,6
    6 IK(1)=IK(2)
      IK(2)=IBK
      BMX(1)=BMX(2)
      BMX(2)=BIMAX
      DO 7 I=1,NUB
      OLDTAU(1,I)=OLDTAU(2,I)
    7 OLDTAU(2,I)=  ATAU(1,I)
      RETURN
    8 IF(ABS(BIMAX)-ABS(BMX(1))*.9) 6,13,13
   13 IF(ABS(BIMAX)-ABS(BMX(1))*1.1) 12,12,6
   12 IF(BIMAX*BMX(1)) 6,6,14
   14 JTEST = 2
      LOW = 1
      DO 16 I=1,NUB
      XTAU(1,I)=ATAU(1,I)
C     WRITE (6,100) NUB,   ATAU(1,I), OLDTAU(2,I), OLDTAU(1,I)
   16 ATAU(1,I)=.4 * ATAU(1,I) + .6*OLDTAU(2,I)
      RETURN
   17 IF(MID.GT.0) GO TO 19
      DO 18 I = 1, NUB
   18 ATAU(1,I) = .6000 * XTAU(1,I) + .4000 *OLDTAU(2,I)
      JTEST = 2
      MID = 1
      LOW = 2
      RETURN
   19 DO 20 I = 1, NUB
   20 ATAU(1,I)=.500*XTAU(1,I)+.500*OLDTAU(2,I)
      JTEST = 2
      MID = 0
      LOW = 0
      JRUN = 0
C     IRUN = ITEMAX + 10
      RETURN
      END
```

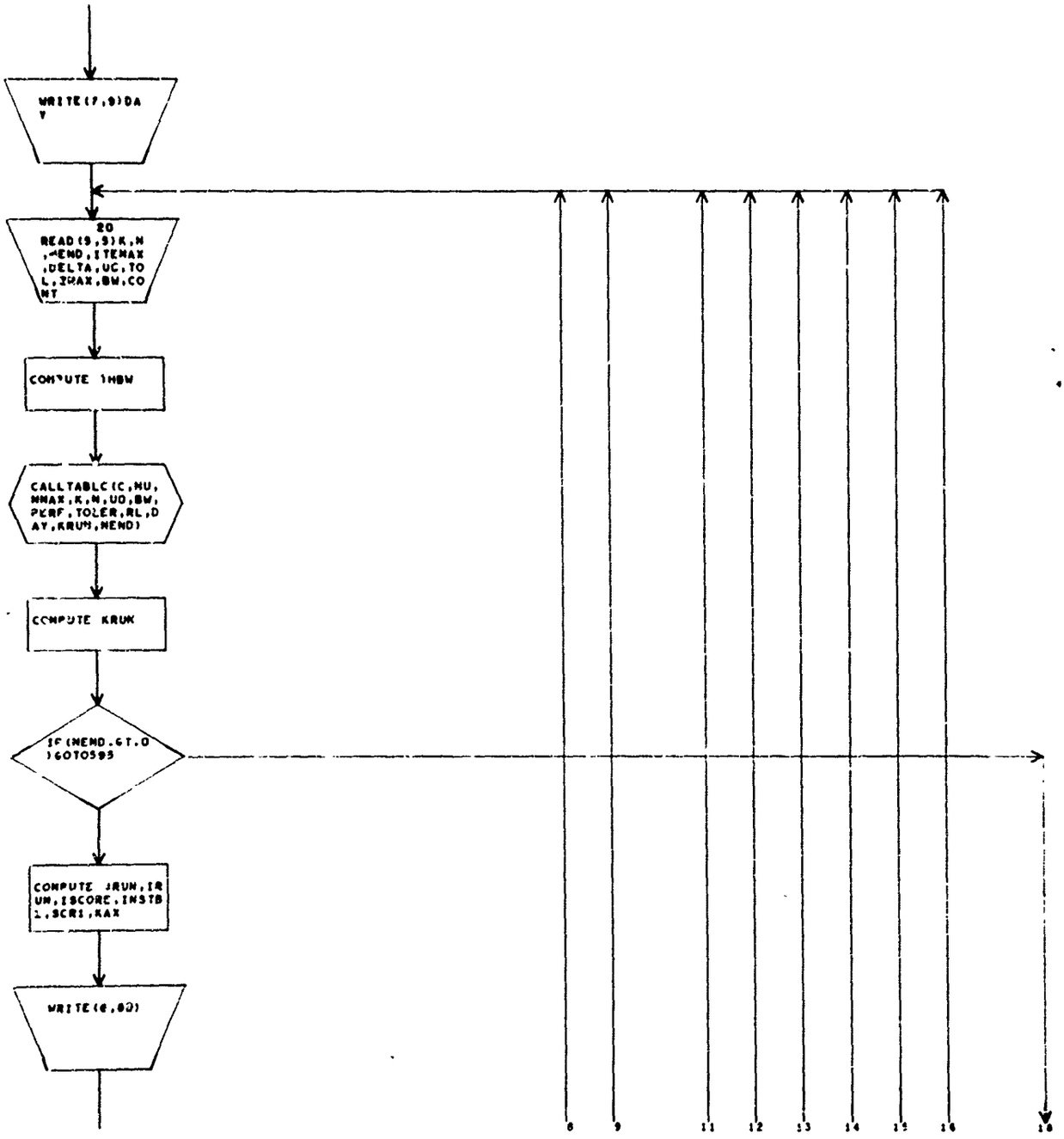
```
      SUBROUTINE TABLC(CT,NUT,NMAXT,KT,NT,UDT,BWT,RIPT,TOLT,RLT,DATE ,
     C  KRUN,NEND)
C
C
C     THIS PROGRAM PREPARES TABLES OF DESIGN DATA GROUPED BY KT,NT,BWT.
C
C     THIS PROGRAM REQUIRES THE IMX SUBROUTINE
C
      DIMENSION TOL(10),RIP(10),C(10,30,10),NL (30),RL(10),CT(10,30),
     Z     NU(10,10),NUM(30),NUU(30) ,DATE(2) ,BAND(20)
   10 FORMAT( 3X2HZ(,I1,1H,I2,1H),2X10F 9.5)
C  10 FORMAT( 3X2HZ(,I1,1H,I2,1H),2X10F10.5)
  886 FORMAT (1X2HN= ,I2,78X10HCOUPLING= , F6.2, 3H DB)
  906 FORMAT (1X2HN=,I2,75X12HPHASE SHIFT=,F6.1,4H DEG)
C   91 FORMAT (2X10HBANDWIDTH , 10F10.3 )
    91 FORMAT (1X11HBANDWIDTH  ,10F 9.3 )
    92 FORMAT(1X11HRIPPLE, DEG,10F 9.5)
    94 FORMAT(1X11HTOLERANCE *,10F 9.5)
    95 FORMAT(1X19H*  READS IN DEGREES)
    96 FORMAT(1X11HREF. LENGTH,10F 9.5)
    97 FORMAT(1X14H*  READS IN DB)
    98 FORMAT(1X10HRIPPLE, DB,1X10F 9.5)
   100 FORMAT(1H )
   101 FORMAT (1H1)
   102 FORMAT(3X7HDATE * ,2X2A6)
       RAD=57.2957795
       CALL FRBUTV(5)
       IF(NEND.GT.0) GO TO 24
       IF(KRUN) 350,350,24
    24 CONTINUE
       BAND(KRUN + 1) = BWT
       TOL(KRUN)=TOLT
       RIP(KRUN)=RIPT
       RL(KRUN)=RLT
       DO 45 I=1,NMAXT
       IT=NUT(I)
       NU(I,KRUN)=IT
       DO 45 IA=1,IT
       C(I,IA,KRUN)=CT(I,IA)
    45 CONTINUE
       IF(NEND.GT.0) GO TO 200
       IF(NMAX-NMAXT) 47,47,48
    47 NMAX=NMAXT
    48 IF(KRUN-10)50,200,200
    50 IF(KT.NE.KCASE) GO TO 200
       IF(NT.NE.NTEST) GO TO 200
       T1=FLOAT(NT)*UDT
       IF(T1-TEST*.9A) 200,60,55
    55 IF(T1-TEST*1.02) 60,60,200
    60 RETURN
   200 CONTINUE
        WRITE(16,101)
       IF(KCASE) 210,210,250
   210 CONTINUE
       WRITE(16,100)
```

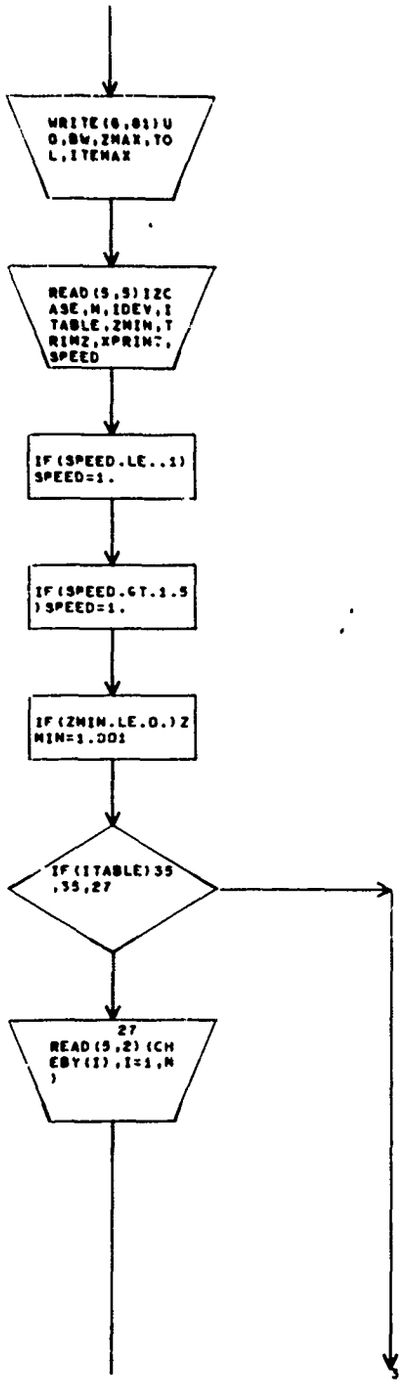
```
      WRITE(16,100)
      WRITE(16,906)NTEST,U1
      WRITE(16,100)
      WRITE (16,100)
      NUM(1)= NTEST
      IF(MMAX-1) 216,216 212
  212 CONTINUE
      DO 214 I2=2,MMAX
      DO 213 NO1= 1,KRUN
  213 NUU(NO1) = NU(I2, NO1)
      NUM(I2)=IMX(KRUN,NUU)
  214 CONTINUE
  216 CONTINUE
      LINE = 15
      WRITE (16,91) ( BAND(J11), J11=1,KRUN)
      WRITE(16,92) (RIP(J11),J11=1,KRUN )
      WRITE(16,94) (TOL(J11),J11=1,KRUN )
      WRITE(16,96) ( RL(J11),J11=1,KRUN )
      DO 220 J1=1,MMAX
      WRITE (16,100)
      WRITE (16,100)
      ITA=NUM(J1)
      DO 220 J2=1,ITA
      WRITE(16,10) J1,J2,(C(J1,J2,J3) ,J3=1,KRUN )
C     LINE=LINE+1
      DO 220 J3=1,KRUN
      C(J1,J2,J3)=DOTS
  220 CONTINUE
  230 KRUN=0
      GO TO 350
  250 CONTINUE
      WRITE (16,100)
      WRITE (16,100)
      U2=20.*ALOG10(SIN(U1/RAD))
      NTX=2**NTEST-1
      WRITE(16,886) NTX,U2
      WRITE (16,100)
      WRITE (16,100)
      NUM(1)= NTEST
      IF(MMAX-1) 266,266,262
  262 CONTINUE
      DO 264 I2=2,MMAX
      DO 263 NO1= 1,KRUN
  263 NUU(NO1) = NU(I2, NO1)
      NUM(I2)=IMX(KRUN,NUU)
  264 CONTINUE
  266 CONTINUE
      LINE = 14
      WRITE (16,91) ( BAND(J11), J11=1,KRUN)
      WRITE(16,98) (RIP(J11),J11=1,KRUN )
      WRITE(16,94) (TOL(J11),J11=1,KRUN )
      DO 270 J1=1,MMAX
      WRITE (16,100)
      WRITE (16,100)
      ITA=NUM(J1)
      DO 270 J2=1,ITA
      WRITE(16,10) J1,J2,(C(J1,J2,J3) ,J3=1,KRUN )
      LINE=LINE+1
      WRITE( 6,10) J1,J2,(C(J1,J2,J3) ,J3=1,KRUN )
      DO 270 J3=1,KRUN
      C(J1,J2,J3)=DOTS
  270 CONTINUE
      KRUN=0
  350 TEST=FLOAT(NT)*UOT
      MMAX=0
      BAND(1 ) = BWT
      U1=UOT
      KCASE=KT
      NTEST=NT
      RETURN
      END



      FUNCTION IMX(. ,N )
C
C     FUNCTION IMX WILL FIND THE MAXIMUM VALUE IN THE IN ARRAY OF SIZE N
C
      DIMENSION IN(500)
  101 FORMAT ( 42H THE DIMENSION IN FUNCTION IMX IS EXCEEDED    )
      IF(N-500) 10,10,100
   10 IMX=IN(1)
      DO 1 I=1,N
      IF(IMX-IN(I)) 2,1,1
    2 IMX=IN(I)
    1 CONTINUE
      GO TO 200
  100 WRITE(6,101)
  200 RETURN
      END
```

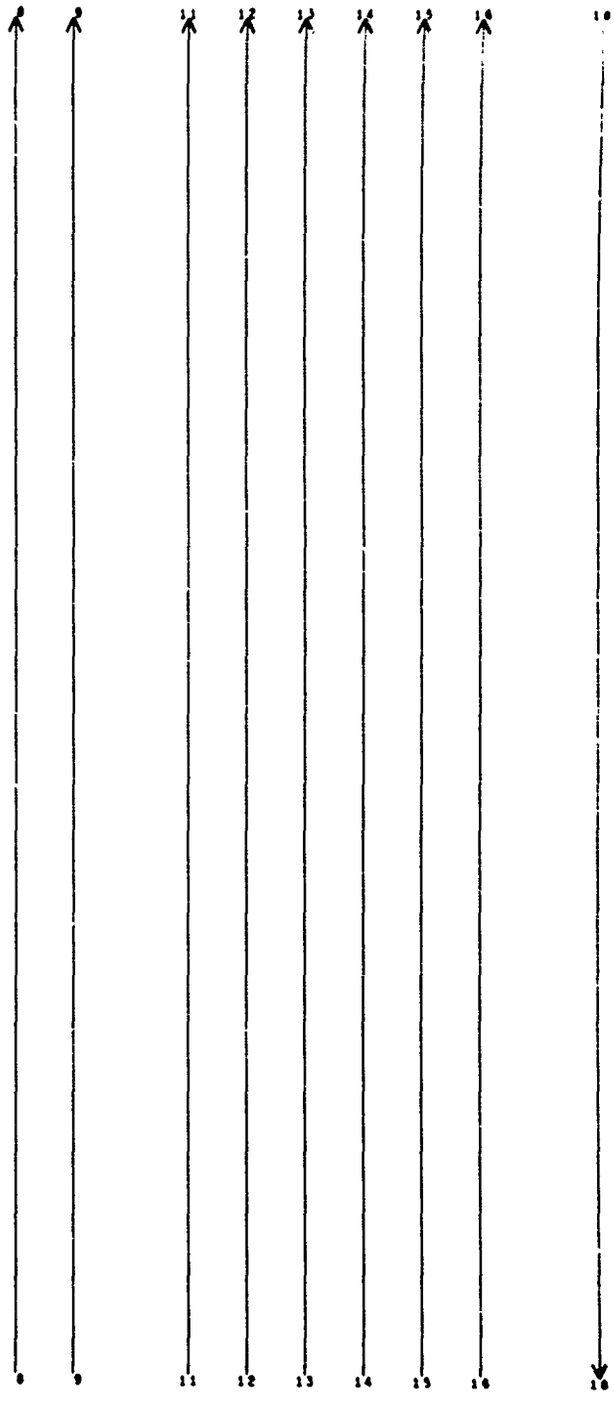
Section 3. FLOW CHART OF THE PROGRAM

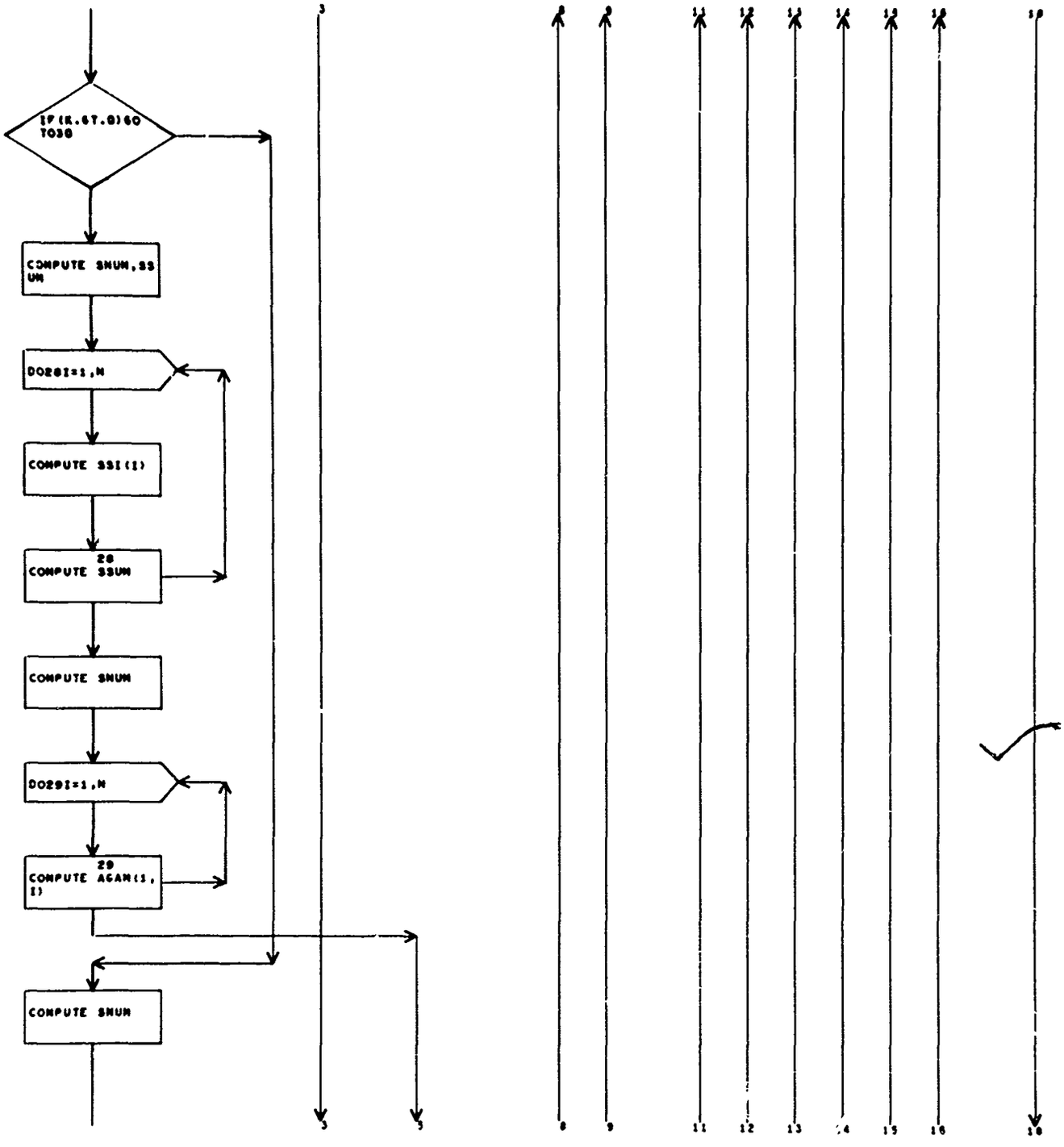
Using an automatic program with the SC4020, a lineal flow chart was prepared of the previous program. Because of the lineal display and the number of pages that are required, wherever possible, two "frames" were placed on a single page in the report. Thus, on page 19, for instance, the heavy broken line represents the proper sequence of events. In the absence of this broken line, it will be understood that flow lines at the top on one page directly connect to lines at the bottom of the immediately preceding page.

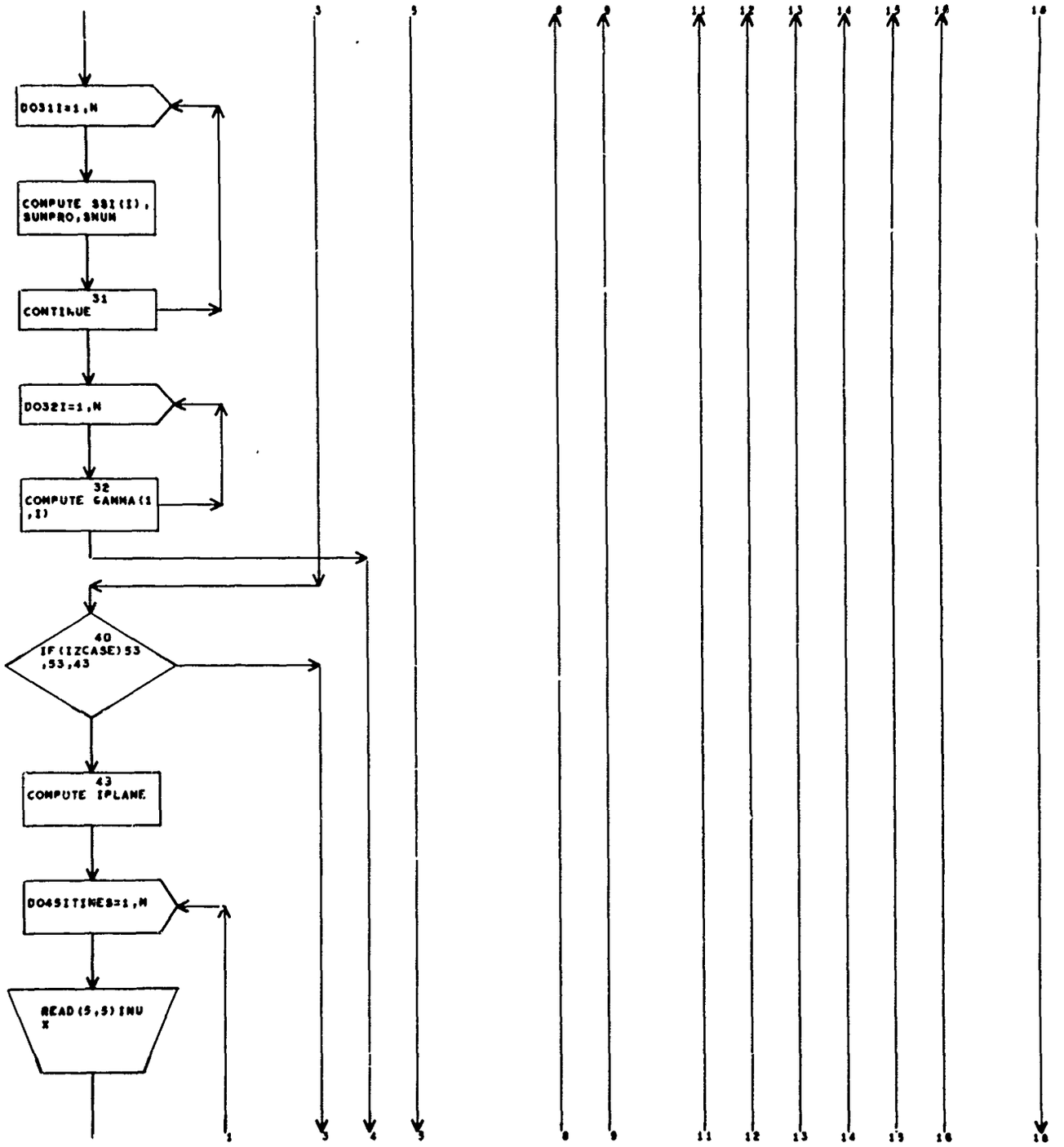

1-061669A
BEGIN MAIN PROG RAM
CALL3COUTV(1,15)
CALLRITSTV(18,26,TABL1V)
CALLMAXFRM(300)
WRITE(16,80)
WRITE(6,105)
COMPUTE RAD
READ(5,9)TOUGH
READ(5,9)PLUMK
READ(5,7)UPPR
READ(5,6)BOTT
READ(5,6)SIDE
COMPUTE KRUN,NPAGE,IZERO,IONE,ITWO,ITHREE,IFOUR
COMPUTE IFIVE,ISIX,ISEVEN,IEIGHT,ININE,ITEN
CALLDATE(DAY)

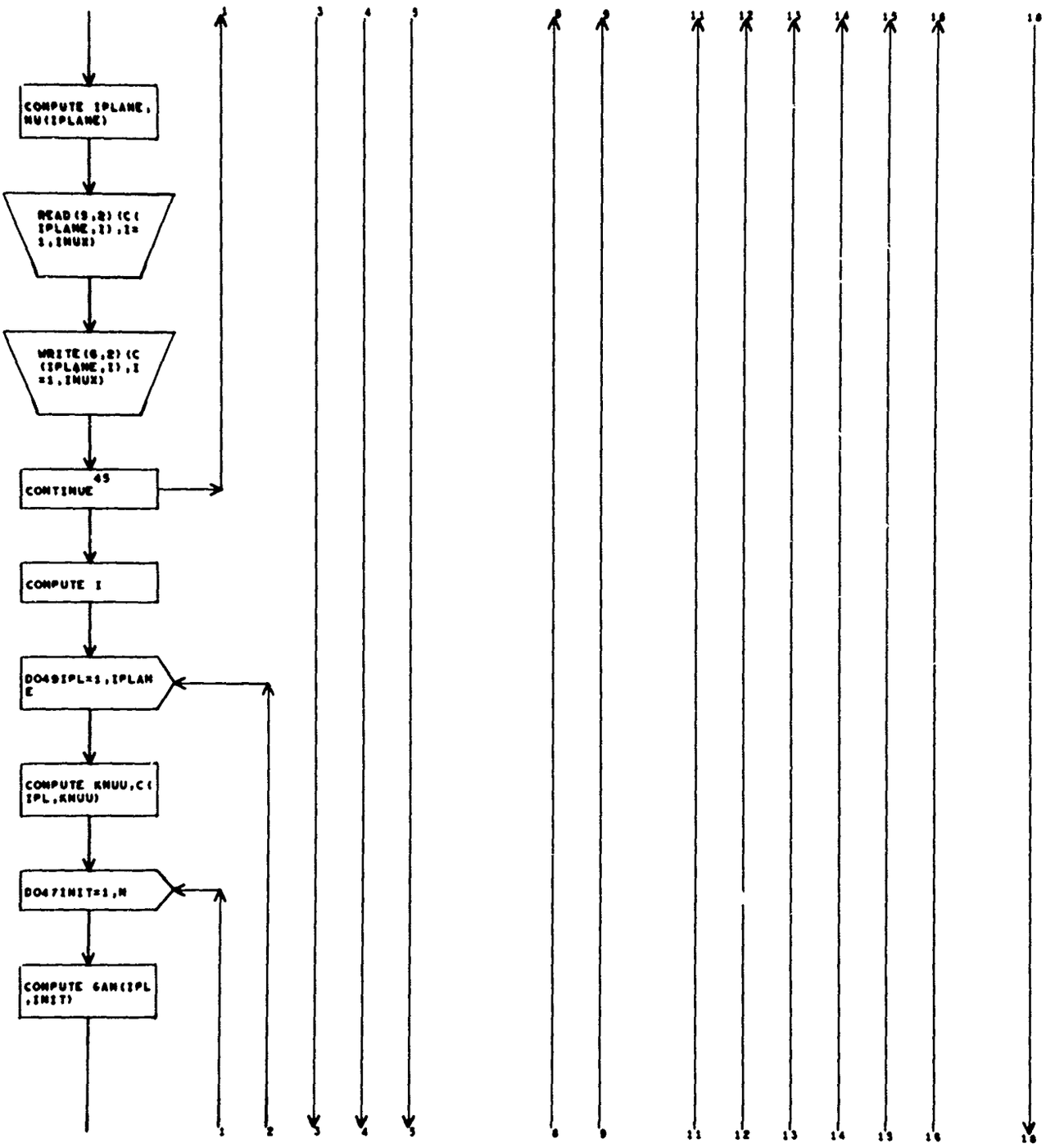

WRITE(7,9)DA
Y
20
READ(9,9)K,N
,MEND,ITEMAX
,DELTA,UC,TO
L,IMAX,BW,CO
NT
COMPUTE IHBW
CALLTABLC(C,MU,
MMAX,K,N,UO,BW,
PERF,TOLER,RL,D
AY,KRUN,MEND)
CCMPUTE KRUN
IF(MEND.GT.0
)GOTO599
COMPUTE JRUN,IR
UN,ISCORE,INSTB
L,SCRI,KAX
WRITE(6,80)
8
9
11
12
13
14
15
16
18

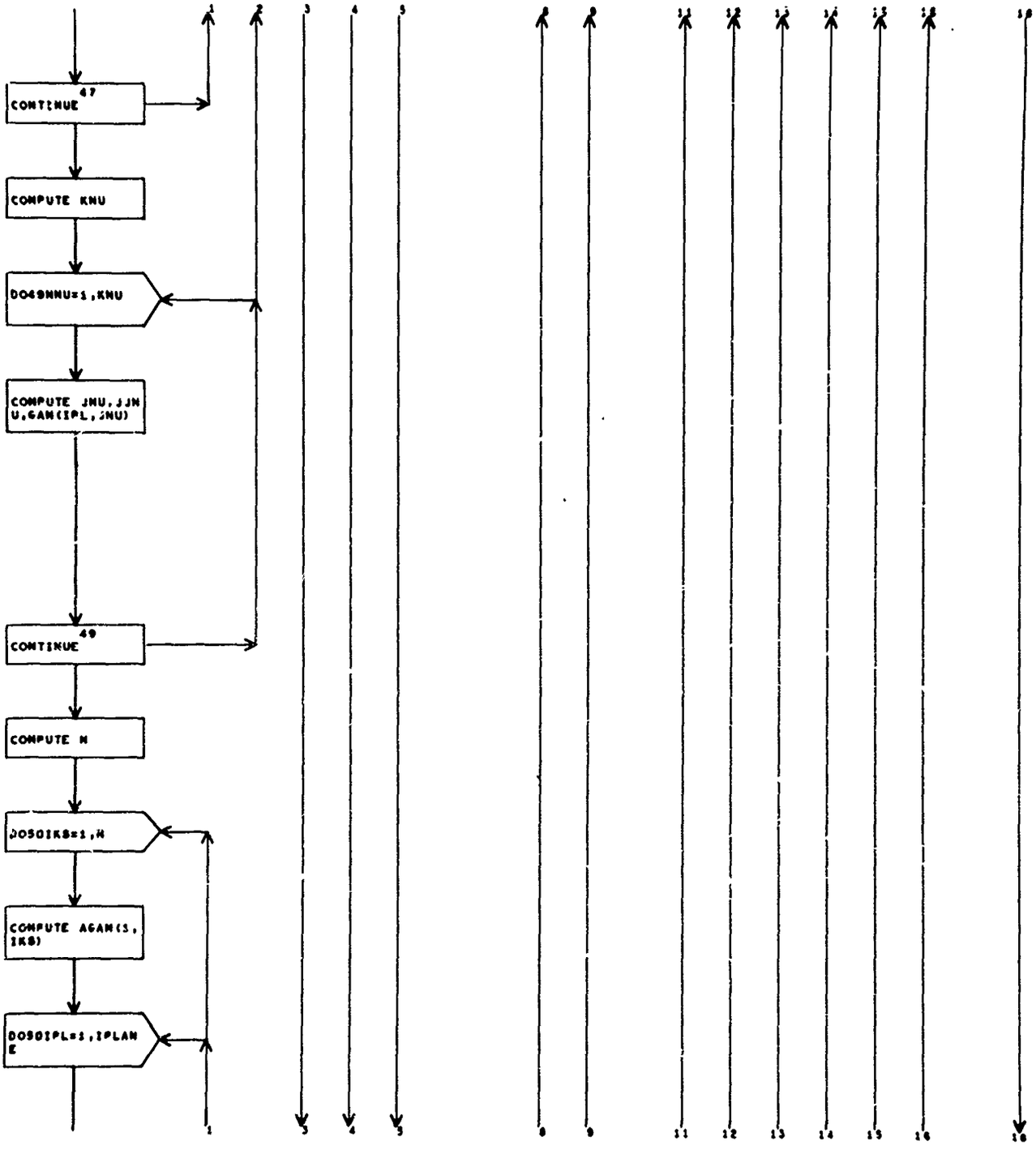

WRITE(6,81)U
0,BW,ZMAX,TO
L,ITEMAX
READ(5,5)IZC
ASE,N,IDEV,I
TABLE,ZMIN,T
RIMZ,XPRINT,
SPEED
IF(SPEED.LE..1)
SPEED=1.
IF(SPEED.GT.1.5
)SPEED=1.
IF(ZMIN.LE.0.)Z
MIN=1.D01
IF(ITABLE)35
,35,27
27
READ(5,2)(CH
EBY(I),I=1,N
)
5

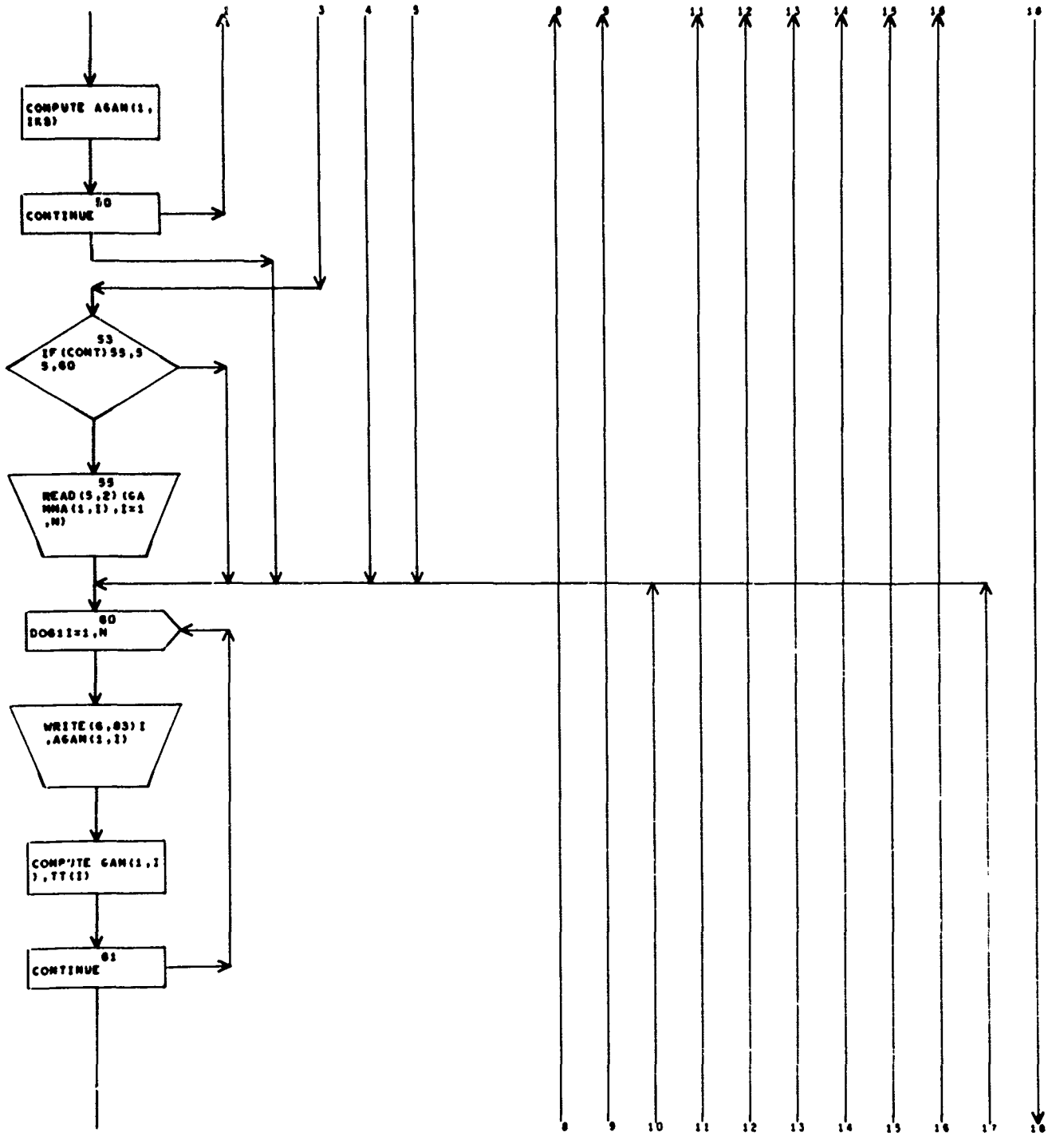

8
9
11
12
13
14
15
16
18
8
9
11
12
13
14
15
16
18

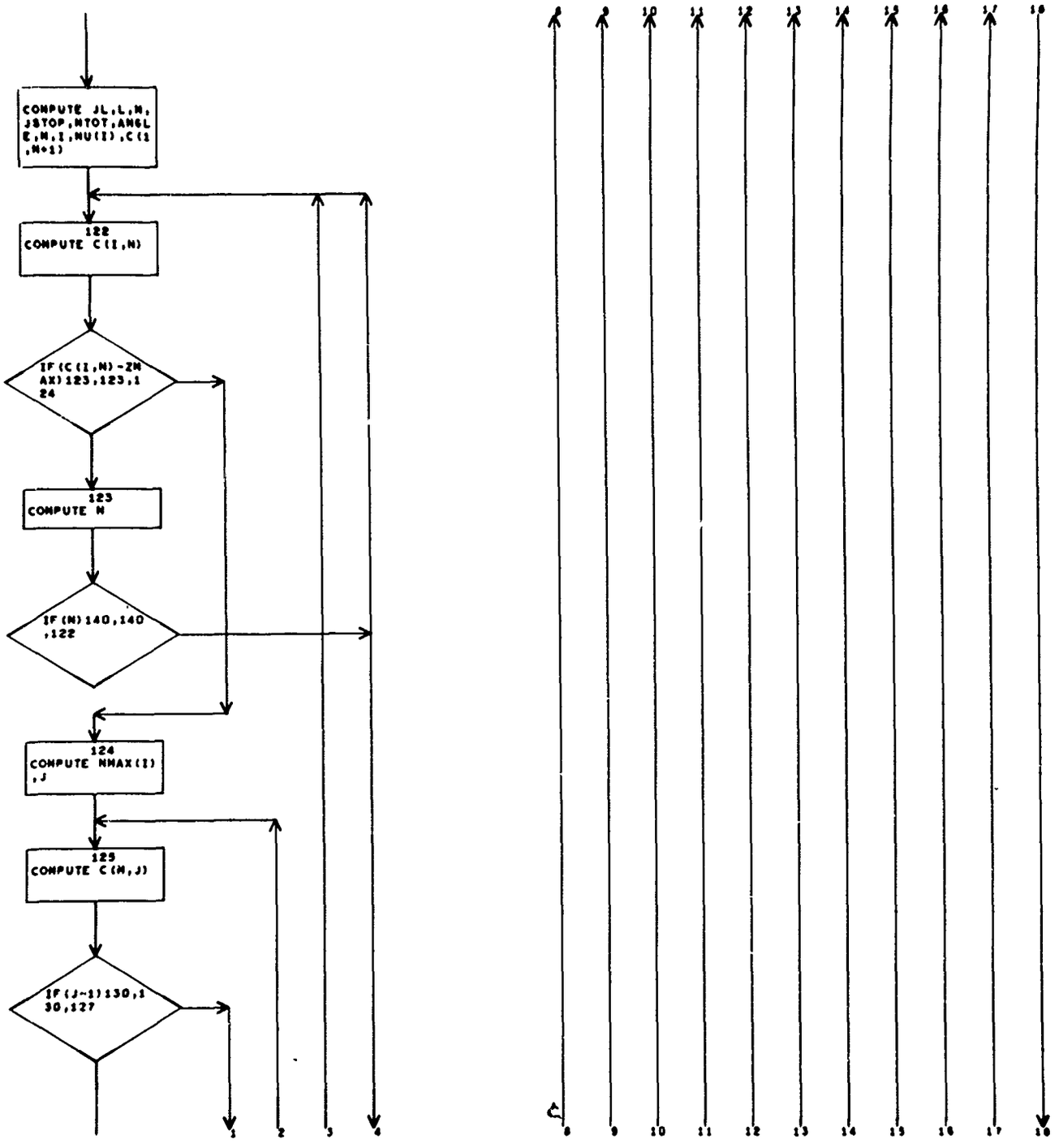

IF(K.GT.0)GO TO30
COMPUTE SNUM,SSUM
DO28I=1,N
COMPUTE SSI(I)
28
COMPUTE SSUM
COMPUTE SNUM
DO29I=1,N
29
COMPUTE AGAM(1,I)
COMPUTE SNUM
3
5
5
8
9
11
12
13
14
15
16
18
18


DO31I=1,N
COMPUTE SSI(I), SUMPRO, SNUM
31 CONTINUE
DO32I=1,N
32 COMPUTE GAMMA(1,I)
40 IF(IZCASE)53,53,43
43 COMPUTE IPLANE
DO45ITIMES=1,N
READ(5,9)INU
X


COMPUTE IPLANE, NU(IPLANE)
READ(5,2)(C(IPLANE,I),I=1,INUX)
WRITE(6,2)(C(IPLANE,I),I=1,INUX)
45 CONTINUE
COMPUTE I
DO49IPL=1,IPLANE
COMPUTE KNUU,C(IPL,KNUU)
DO47INIT=1,N
COMPUTE GAN(IPL,INIT)


CONTINUE 47
COMPUTE KNU
DO49NNU=1,KNU
COMPUTE JNU,JJNU,GAM(IPL,JNU)
CONTINUE 49
COMPUTE M
DO50IKS=1,M
COMPUTE AGAM(1,IKS)
DO50IPL=1,IPLANE


COMPUTE AGAN(1,IRB)
50 CONTINUE
53 IF(CONT)55,55,60
55 READ(5,2)(GAMMA(1,I),I=1,N)
60 DO61I=1,N
WRITE(6,83)I,AGAN(1,I)
COMP'ITE GAN(1,I),TT(I)
61 CONTINUE


COMPUTE JL,L,N, JSTOP,NTOT,ANGL E,M,I,NU(I),C(1 ,N+1)
122
COMPUTE C(I,N)
IF(C(I,N)-2M AX)123,123,1 24
123
COMPUTE N
IF(N)140,140 ,122
124
COMPUTE NMAX(I) ,J
125
COMPUTE C(M,J)
IF(J-1)130,1 30,127
1
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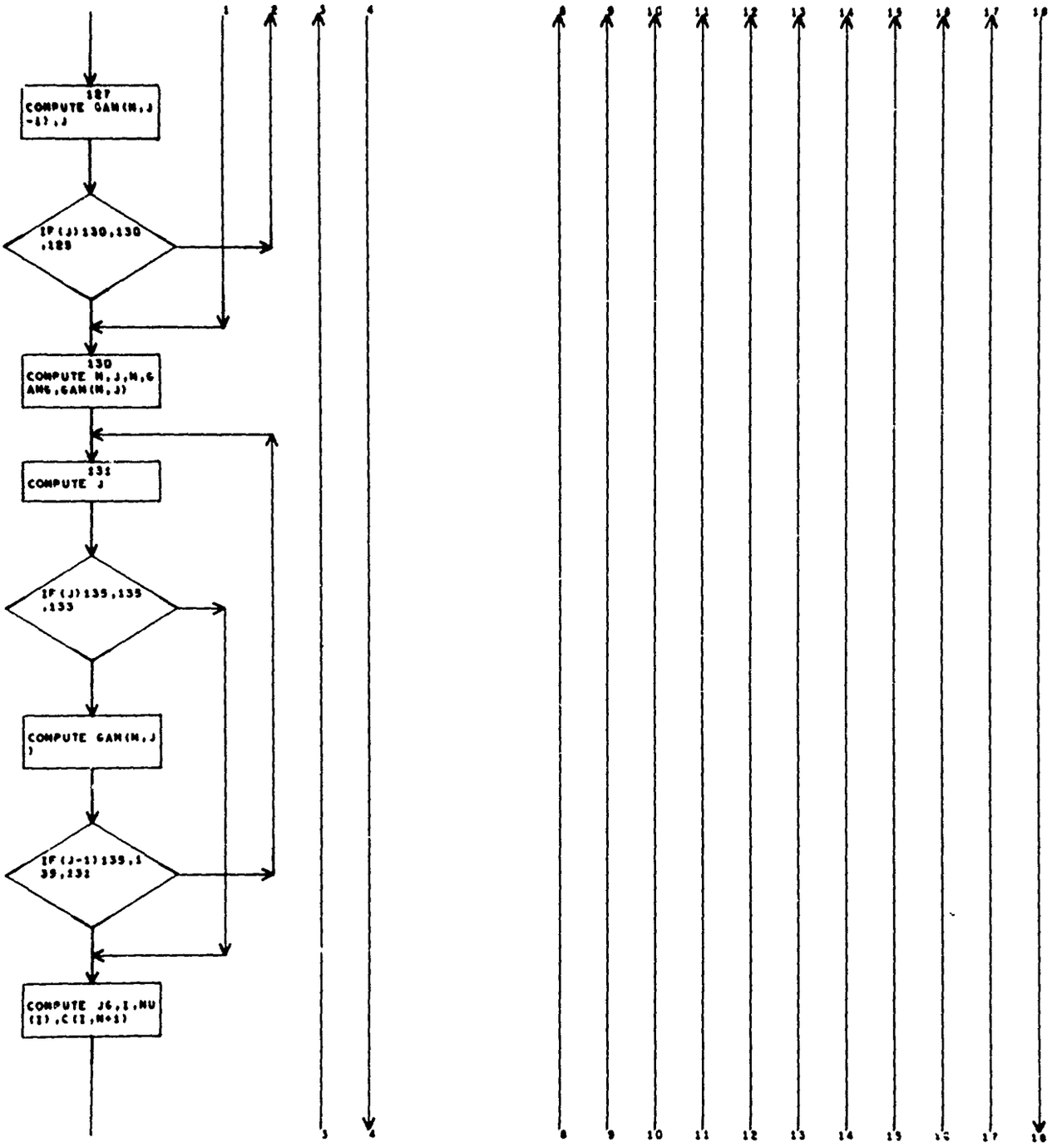
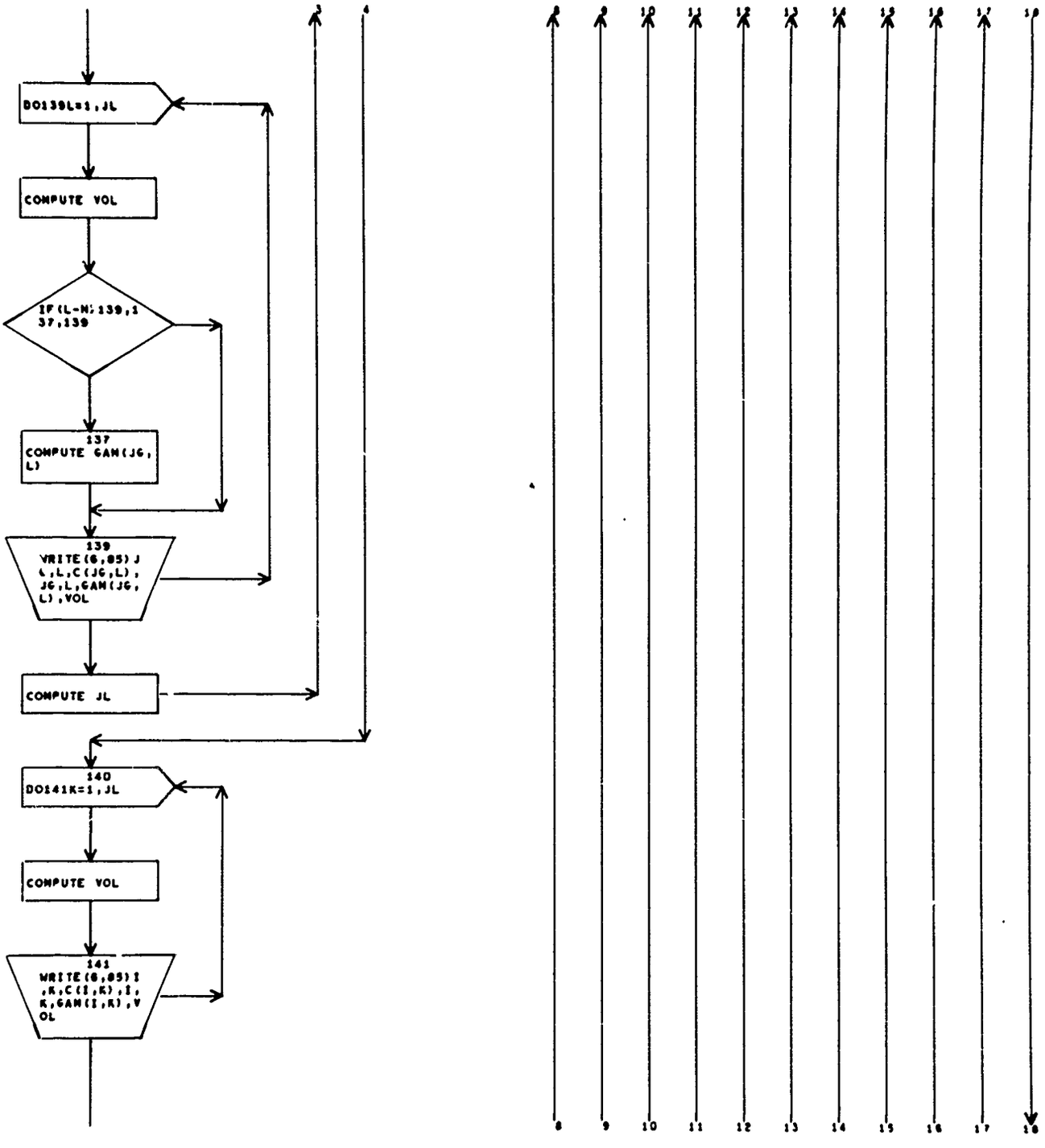
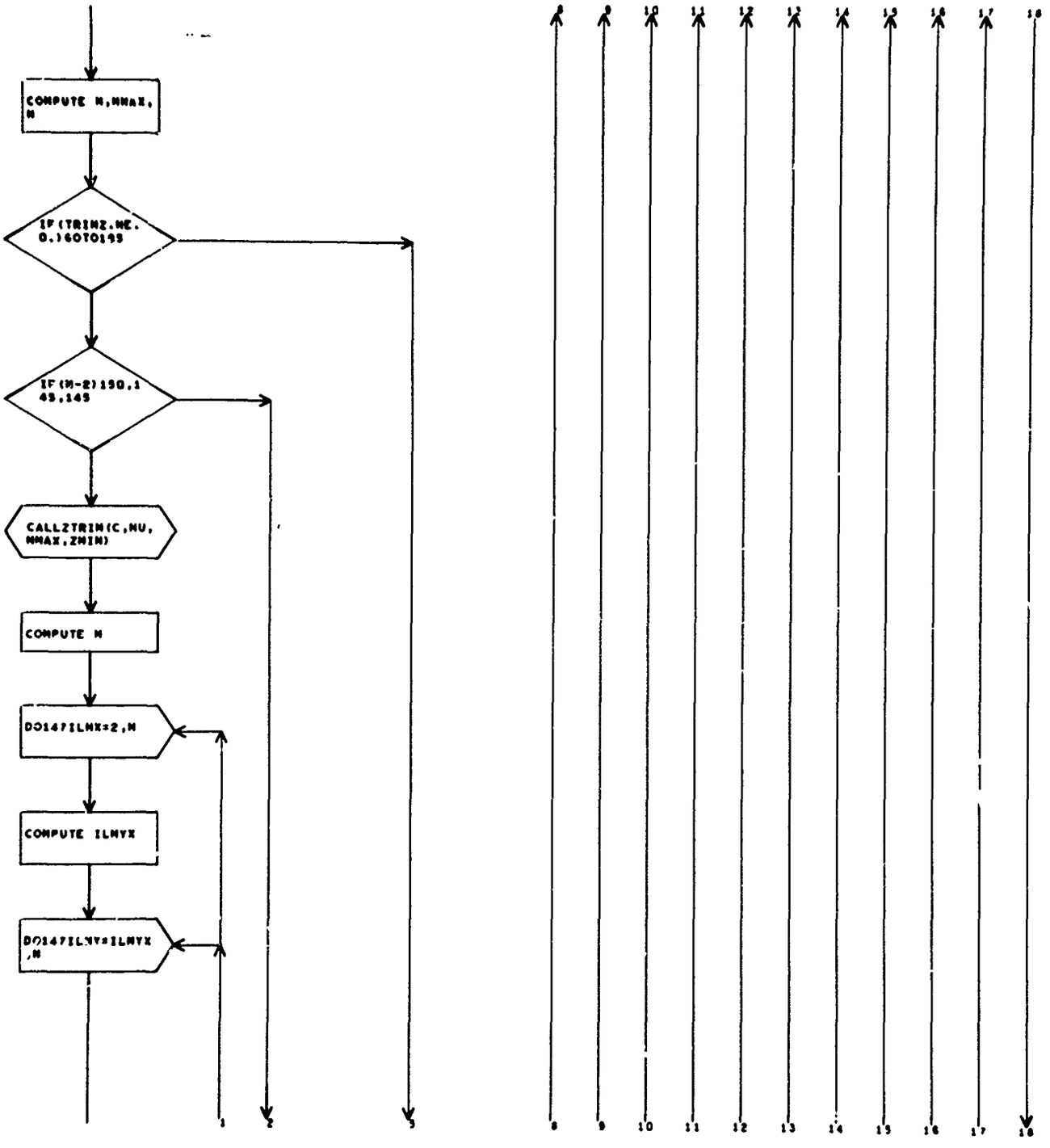

1 2 3 4
127
COMPUTE GAM(N,J-1),J
IF(J)130,130,128
130
COMPUTE N,J,N,GAMG,GAM(N,J)
131
COMPUTE J
IF(J)135,135,133
COMPUTE GAM(N,J)
IF(J-1)139,139,132
COMPUTE J6,I,MU(I),C(I,N+1)
3 4
8 9 10 11 12 13 14 15 16 17 18


DO139L=1,JL
COMPUTE VOL
IF(L-N)139,137,139
137
COMPUTE GAM(JG,L)
139
WRITE(6,85)J,L,C(JG,L),JG,L,GAM(JG,L),VOL
COMPUTE JL
140
DO141K=1,JL
COMPUTE VOL
141
WRITE(6,85)I,K,C(I,K),I,K,GAM(I,K),VOL


COMPUTE N,NMAX,
M
IF(TRINZ.NE.
0.)GOTO198
IF(N-2)190,1
45,145
CALLZTRIN(C,NU,
NMAX,ZMIN)
COMPUTE M
DO147ILNX=2,N
COMPUTE ILNYX
DO147ILNY=ILNYX
,N
1
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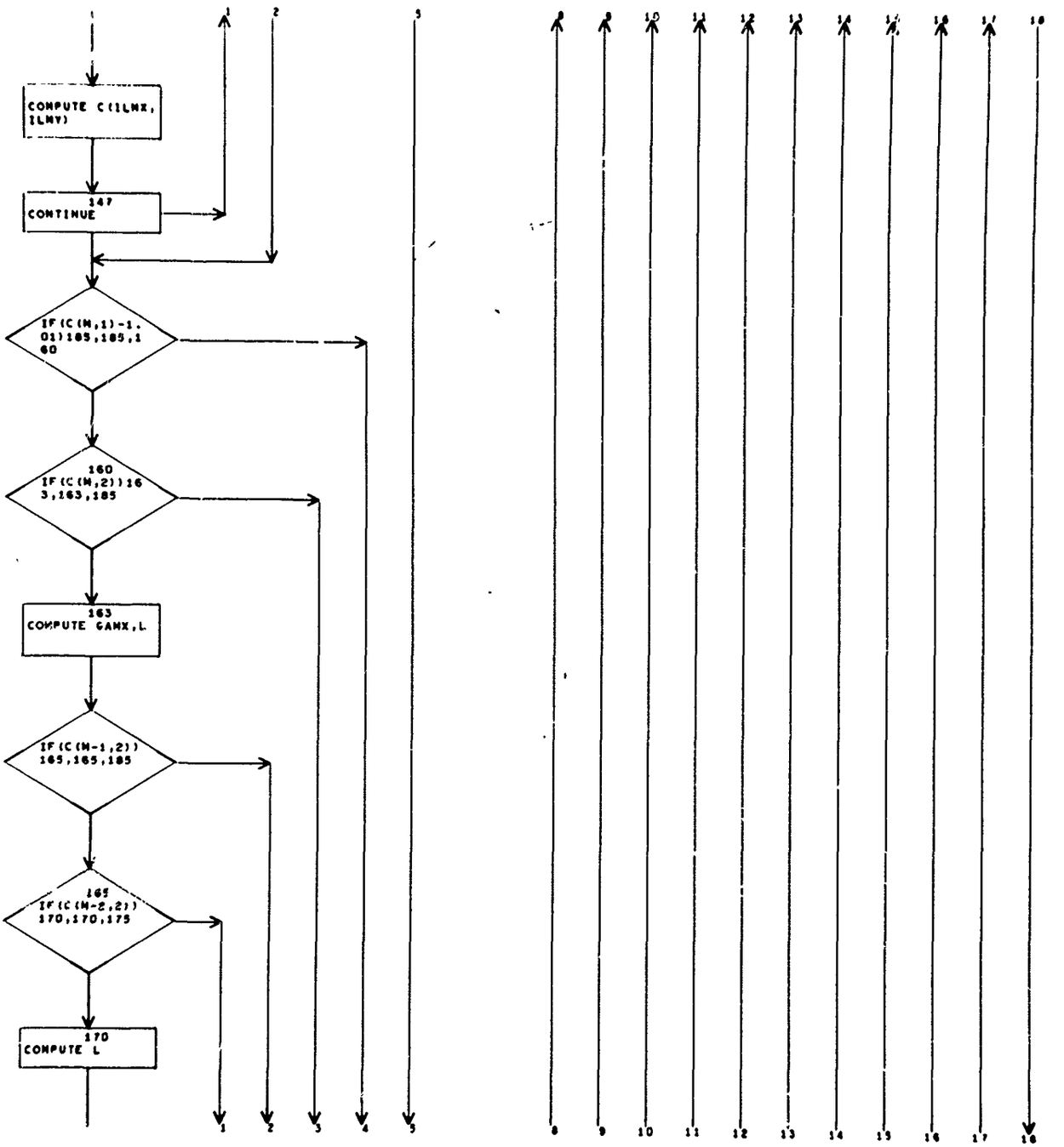
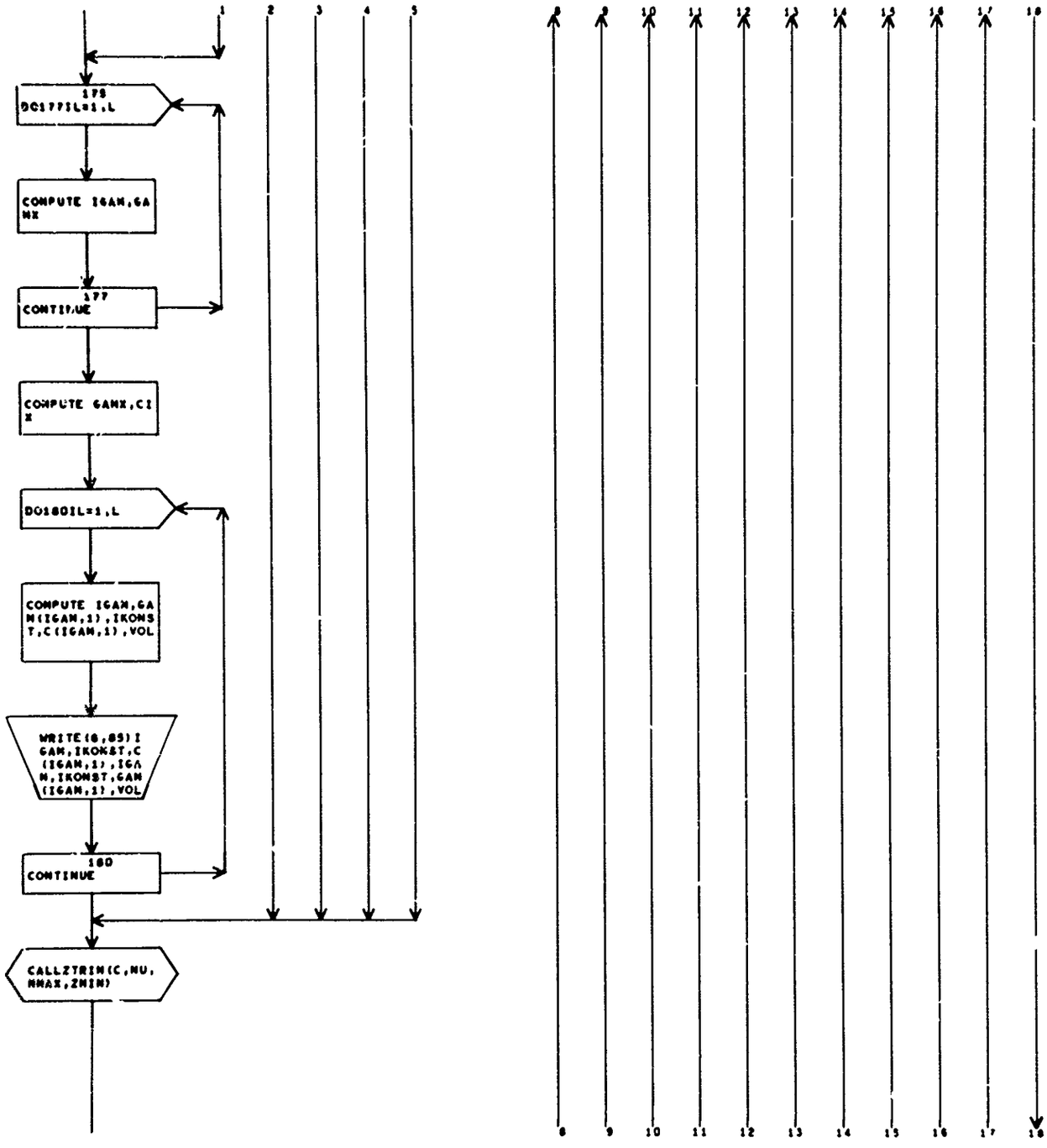
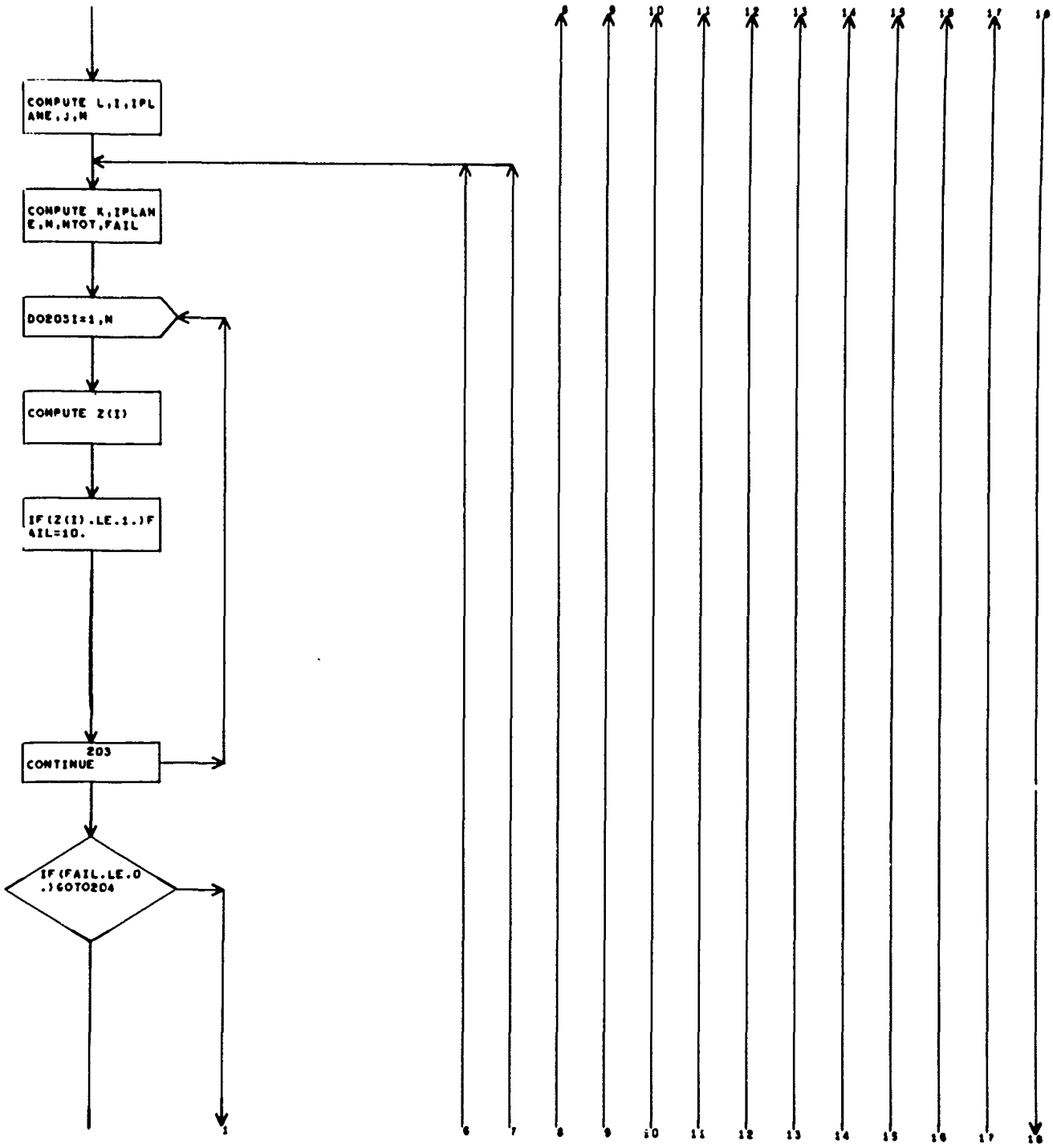

COMPUTE C(ILMX, ILMV)
147 CONTINUE
IF(C(M,1)-1. 01)185,185,1 60
160 IF(C(M,2))16 3,163,185
163 COMPUTE GAMX,L
IF(C(M-1,2)) 165,165,185
165 IF(C(M-2,2)) 170,170,175
170 COMPUTE L


1 2 3 4 5 8 9 10 11 12 13 14 15 16 17 18
175
DO177IL=1,L
COMPUTE IGAM,GAMX
177
CONTINUE
COMPUTE GAMX,CIX
DO180IL=1,L
COMPUTE IGAM,GAM(IGAM,1),IKONST,C(IGAM,1),VOL
WRITE(6,85)IGAM,IKONST,C(IGAM,1),IGAM,IKONST,GAM(IGAM,1),VOL
180
CONTINUE
CALLZTRIN(C,NU,NMAX,ZMIN)
8 9 10 11 12 13 14 15 16 17 18


COMPUTE L,I,IPLANE,J,M
COMPUTE K,IPLANE,N,NTOT,FAIL
DO203I=1,M
COMPUTE Z(I)
IF(Z(I).LE.1.)FAIL=10.
203 CONTINUE
IF(FAIL.LE.0.)GOTO204
1
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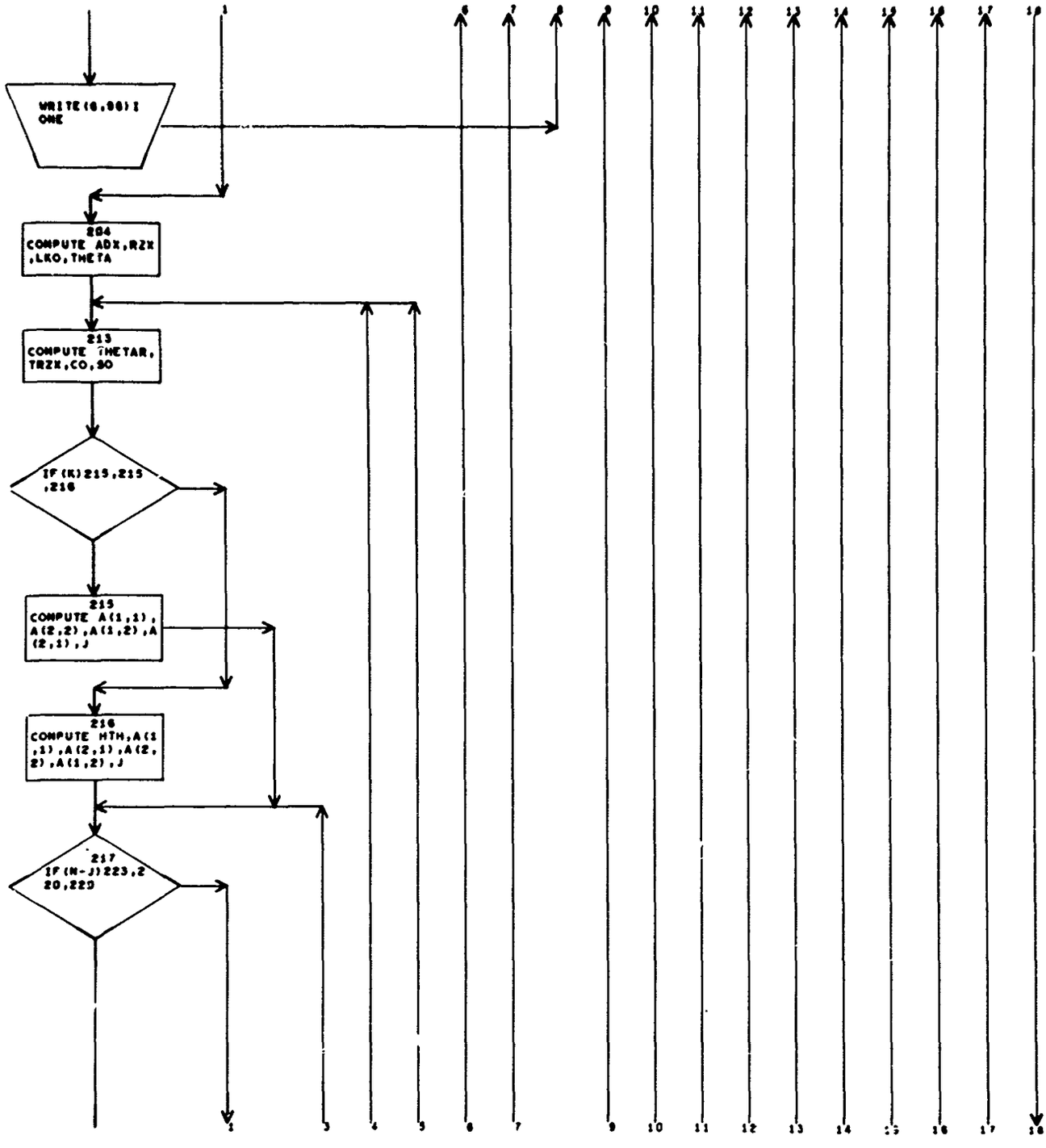
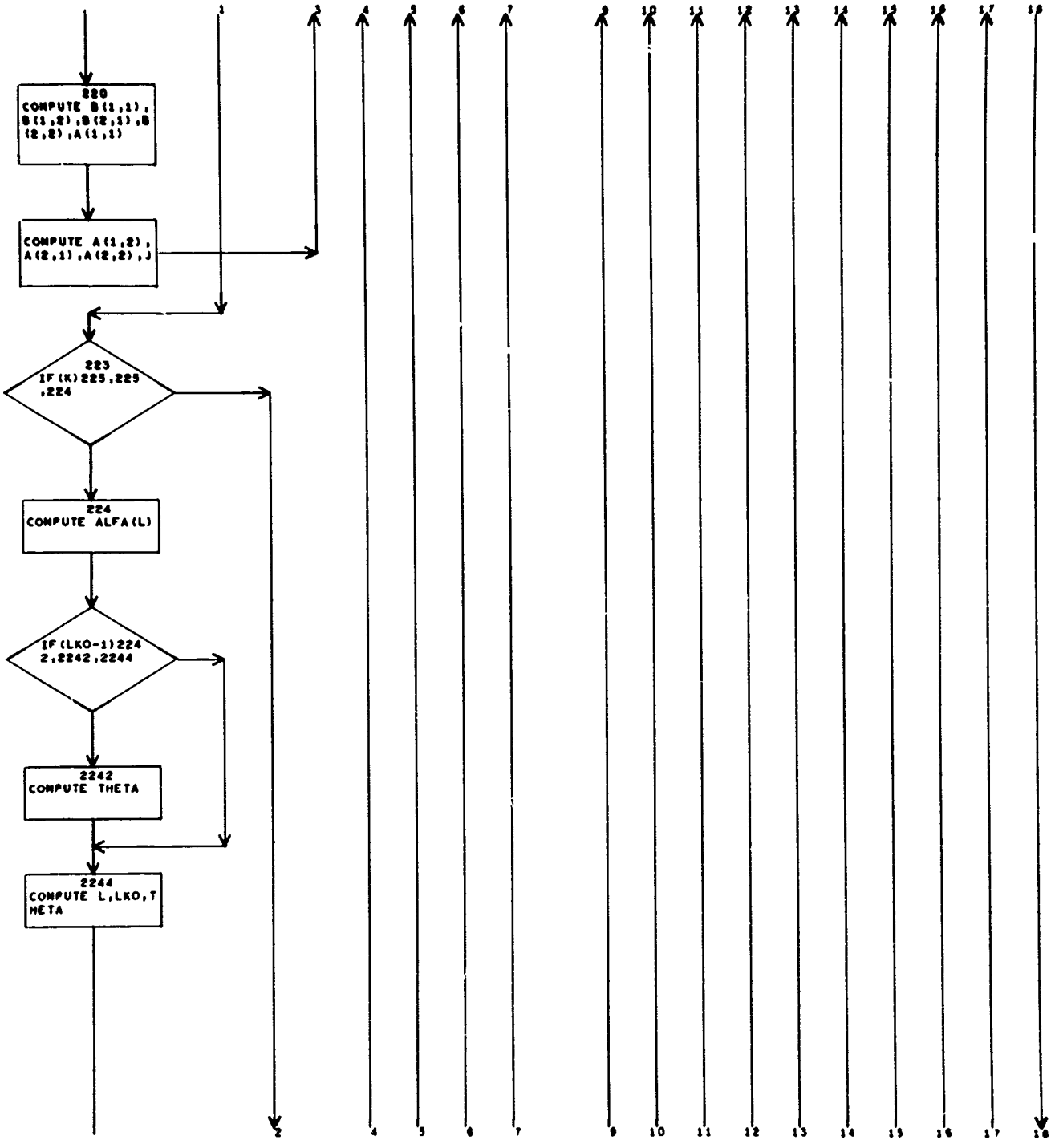
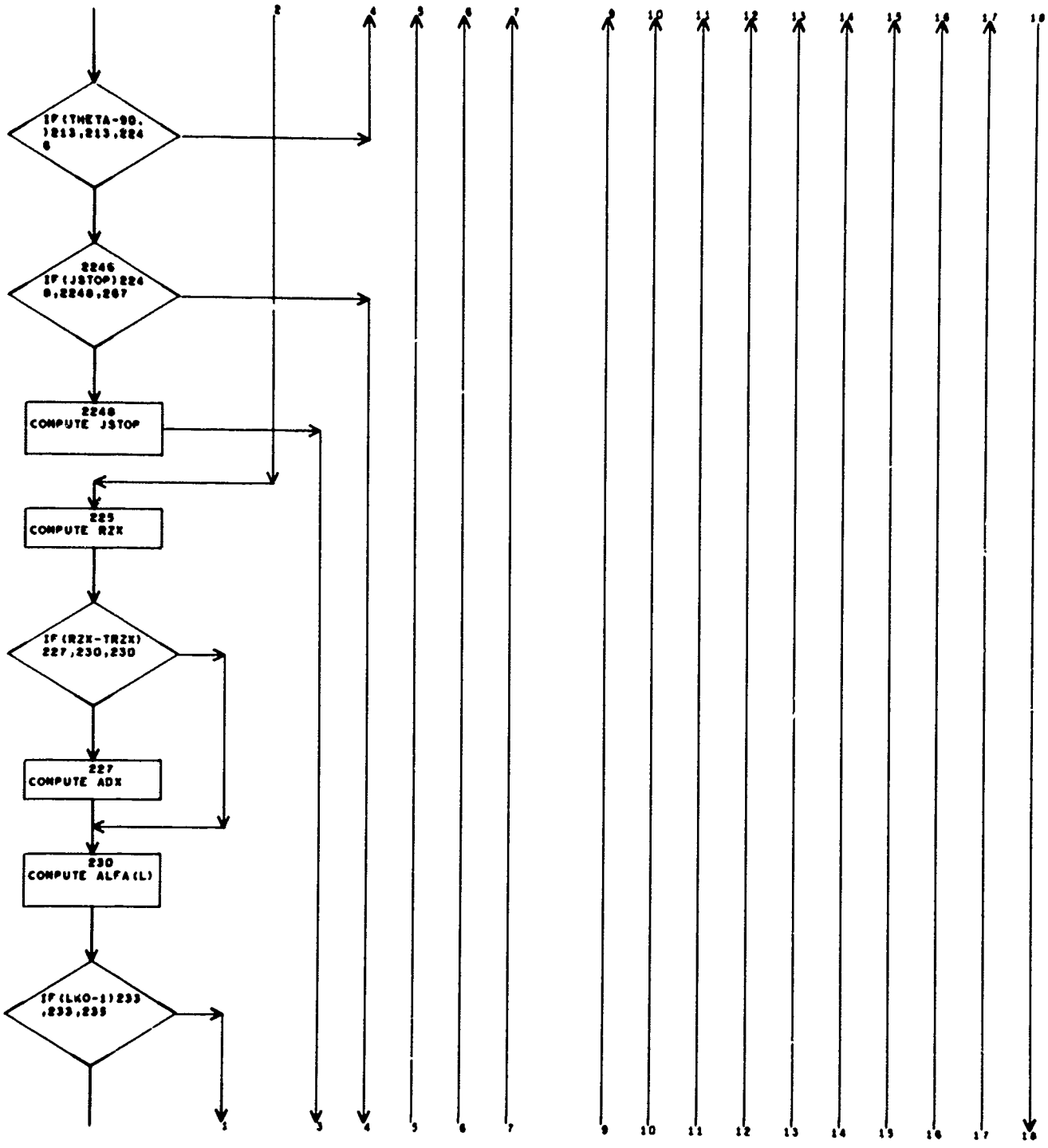
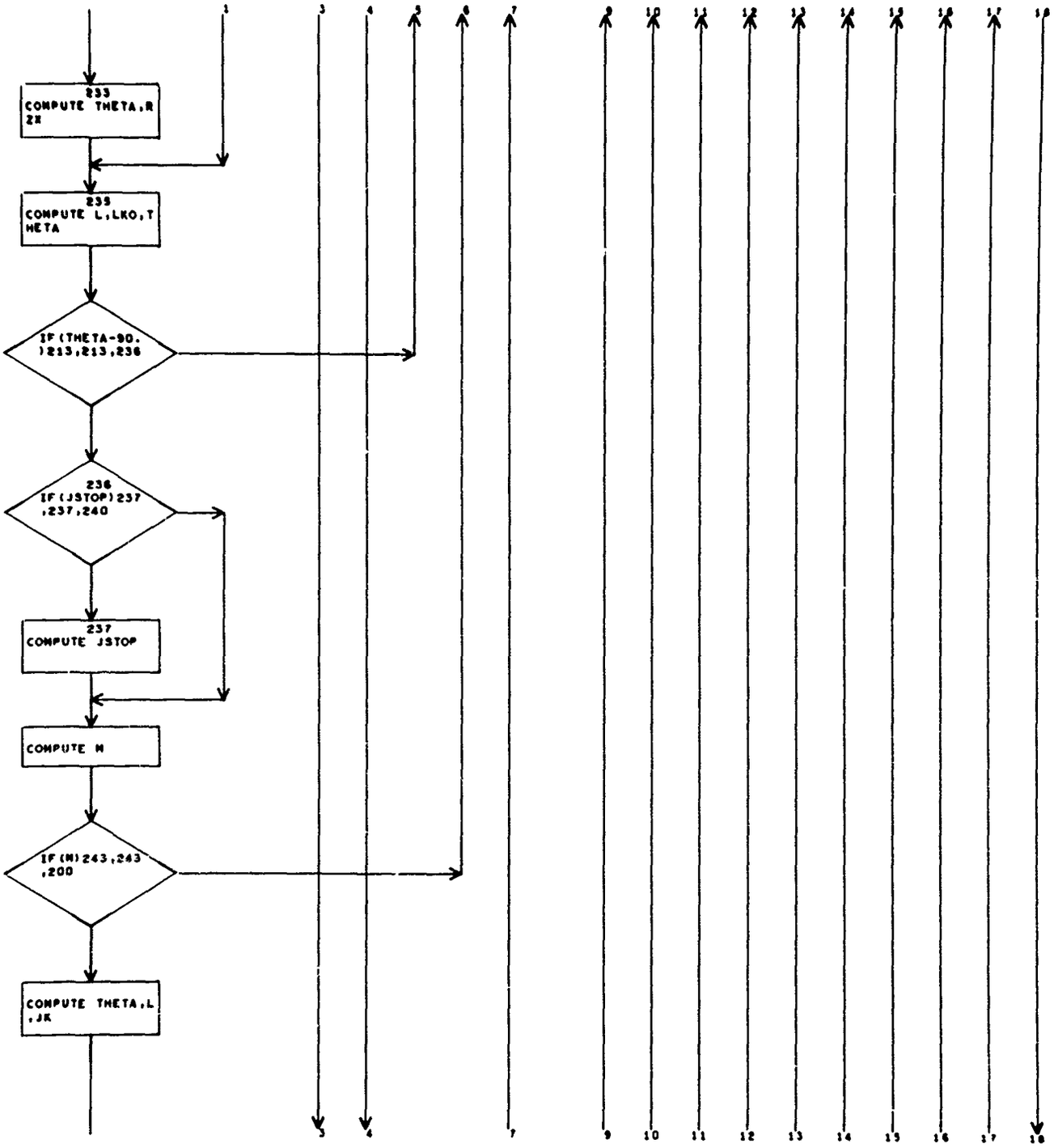
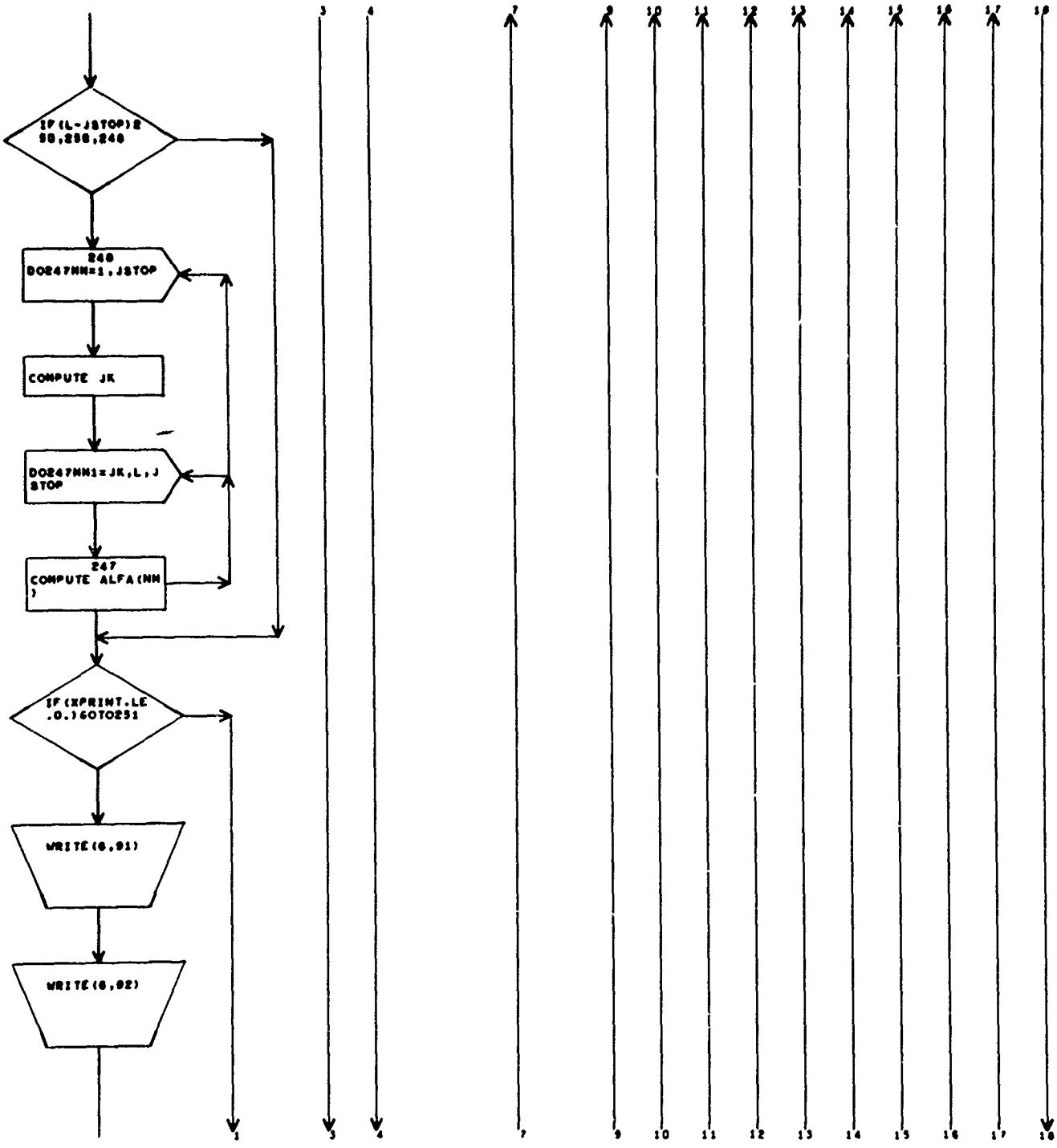

WRITE(6,96)I ONE
204
COMPUTE ADX,RZX ,LKO,THETA
213
COMPUTE THETAR, TRZX,CO,SO
IF(K)215,215 ,216
215
COMPUTE A(1,1), A(2,2),A(1,2),A (2,1),J
216
COMPUTE HTH,A(1 ,1),A(2,1),A(2, 2),A(1,2),J
217
IF(N-J)223,2 20,220


220
COMPUTE B(1,1),B(1,2),B(2,1),B(2,2),A(1,1)
COMPUTE A(1,2),A(2,1),A(2,2),J
223
IF(K)225,225,224
224
COMPUTE ALFA(L)
IF(LKO-1)2242,2242,2244
2242
COMPUTE THETA
2244
COMPUTE L,LKO,THETA


IF(THETA-90.
)213,213,224
6
2246
IF(JSTOP)224
8,2248,267
2248
COMPUTE JSTOP
225
COMPUTE RZX
IF(RZX-TRZX)
227,230,230
227
COMPUTE ADX
230
COMPUTE ALFA(L)
IF(LKO-1)233
,235,235


233
COMPUTE THETA,R
ZX
235
COMPUTE L,LKO,T
HETA
IF(THETA-90.
)213,213,236
236
IF(JSTOP)237
,237,240
237
COMPUTE JSTOP
COMPUTE N
IF(N)243,243
,200
COMPUTE THETA,L
,JK


IF(L-JSTOP)2
50,250,240
240
DO247NN=1,JSTOP
COMPUTE JK
DO247NN1=JK,L,J
STOP
247
COMPUTE ALFA(NN
)
IF(XPRINT.LE
.0.)GOTO251
WRITE(6,91)
WRITE(6,92)
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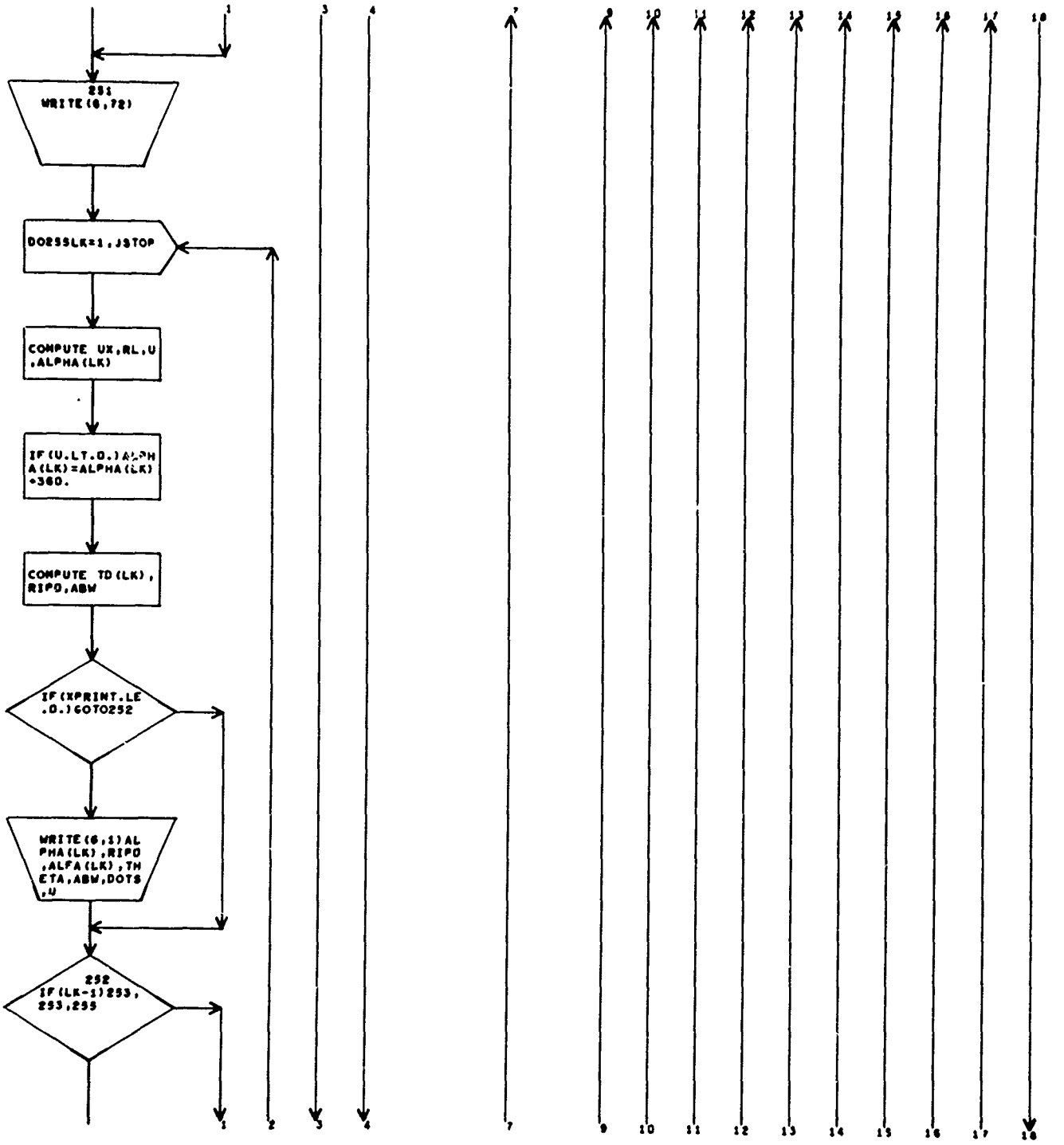
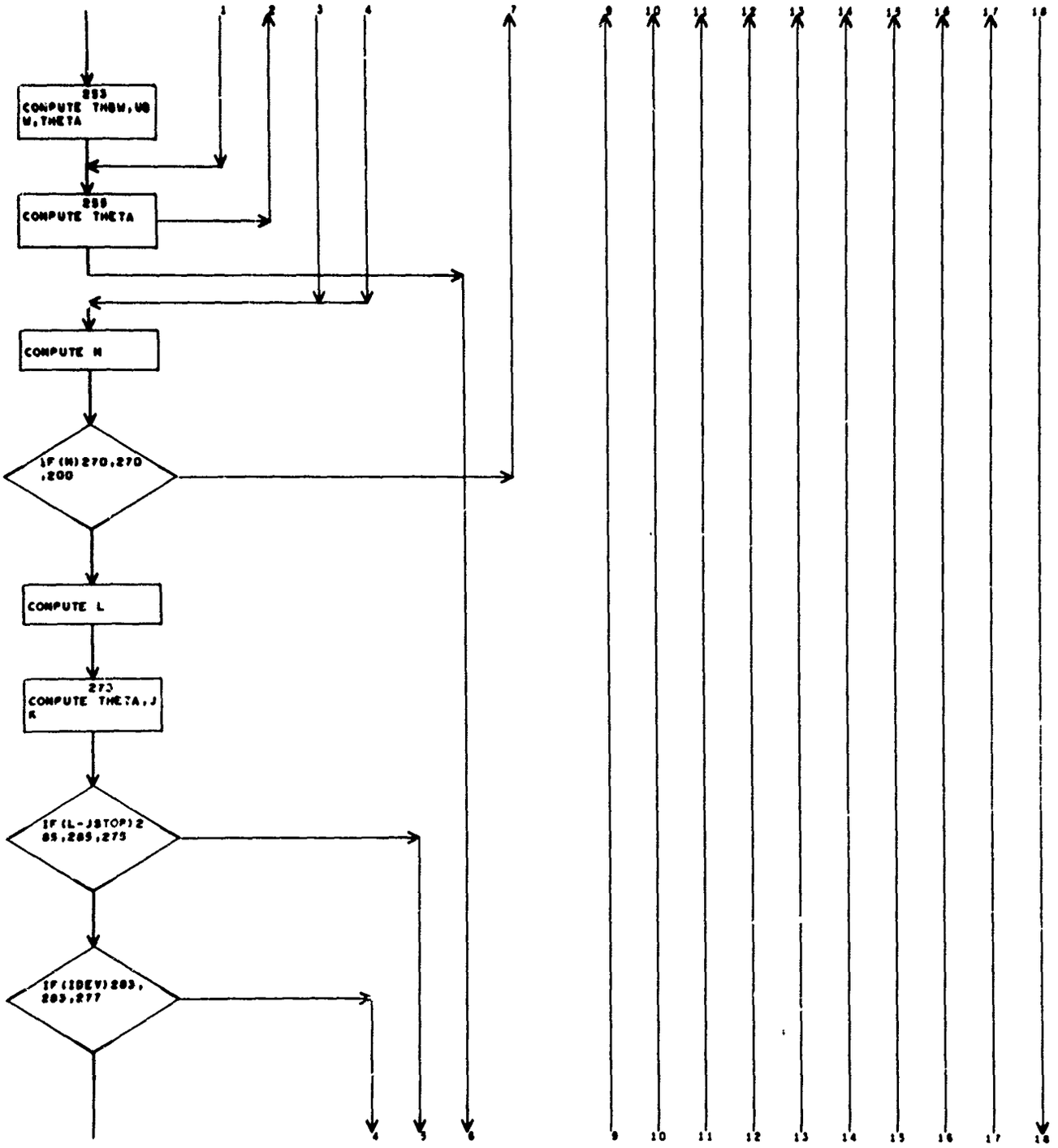

251
WRITE(6,72)
DO255LK=1,JSTOP
COMPUTE UX,RL,U
,ALPHA(LK)
IF(U.LT.0.)ALPH
A(LK)=ALPHA(LK)
+360.
COMPUTE TD(LK),
RIPD,ABW
IF(XPRINT.LE
.0.)GOTO252
WRITE(6,1)AL
PHA(LK),RIPD
,ALFA(LK),TH
ETA,ABW,DOTS
,U
252
IF(LK-1)253,
253,255


1
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18
283
COMPUTE THBW,UB
M,THETA
288
COMPUTE THETA
COMPUTE N
IF(N)270,270
,200
COMPUTE L
273
COMPUTE THETA,J
R
IF(L-JSTOP)2
85,285,275
IF(IDEV)283,
283,277
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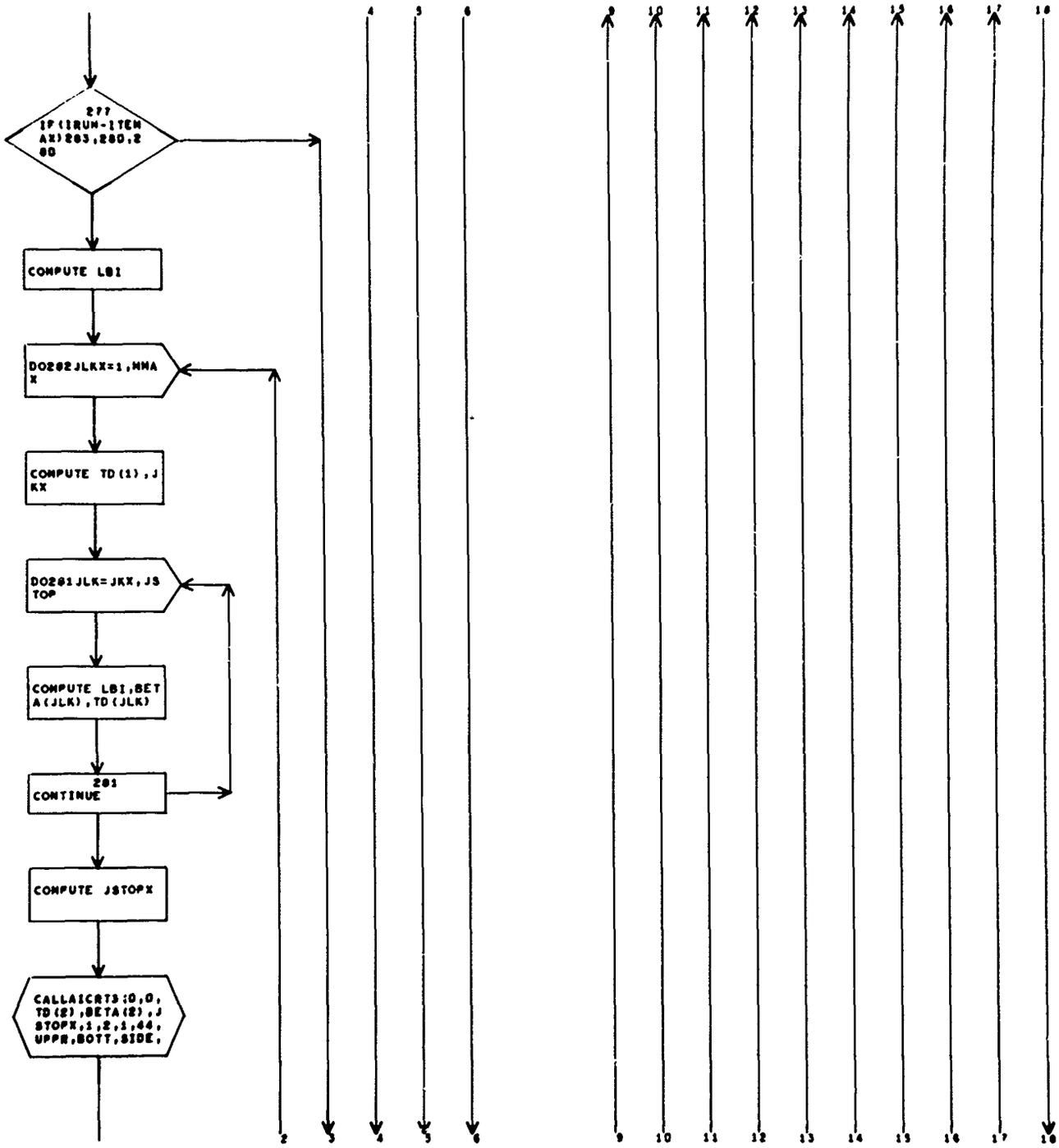
277
IF(IRUN-1TEM
AX)283,280,2
80
COMPUTE LBI
DO282JLKX=1,MMA
X
COMPUTE TD(1),J
KX
DO281JLK=JKX,JS
TOP
COMPUTE LBI,BET
A(JLK),TD(JLK)
281
CONTINUE
COMPUTE JSTOPX
CALLAICRTS(0,0,
TD(2),BETA(2),J
STOPX,1,2,1,44,
UPPR,BOTT,SIDE,
4
5
6
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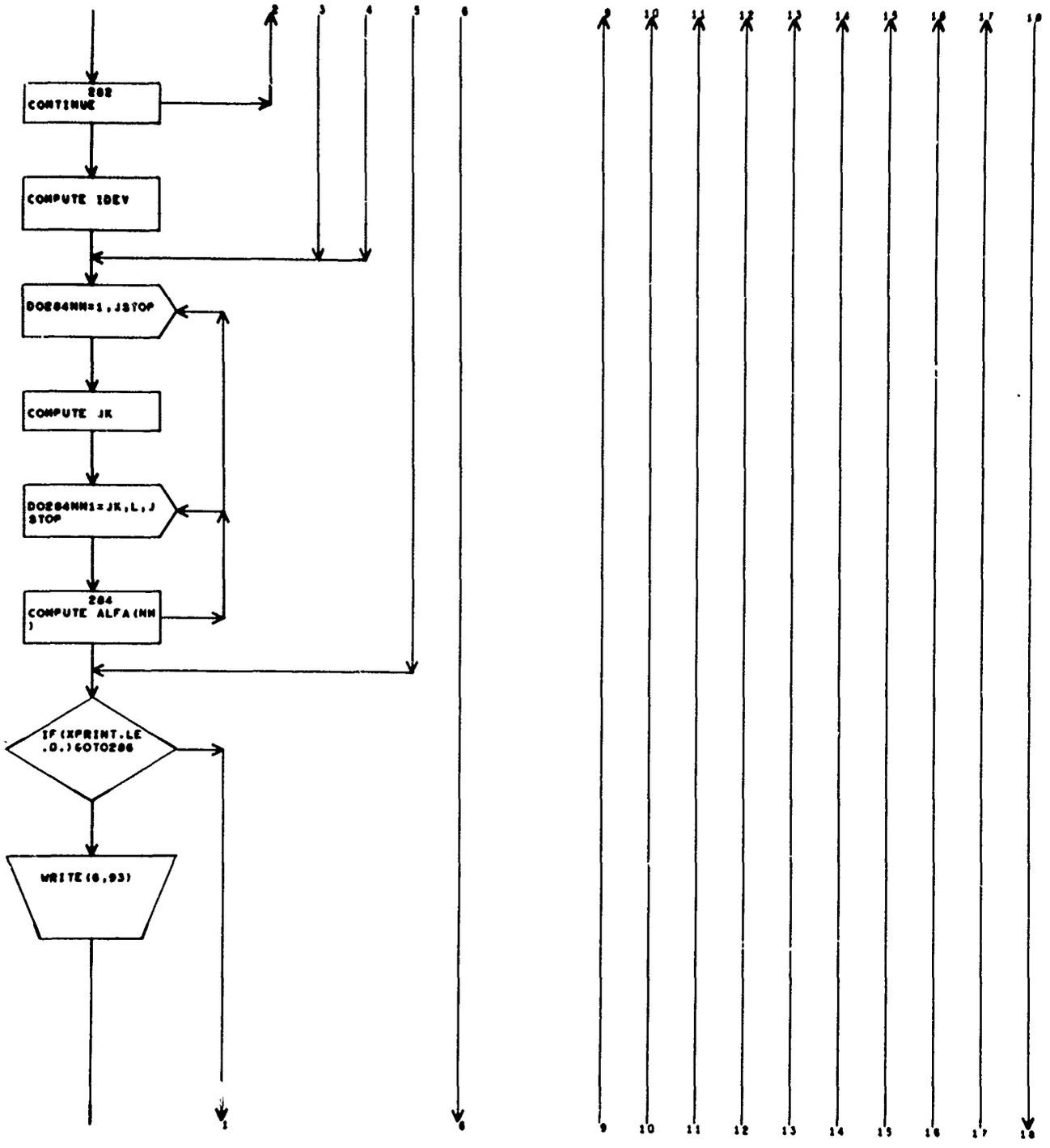
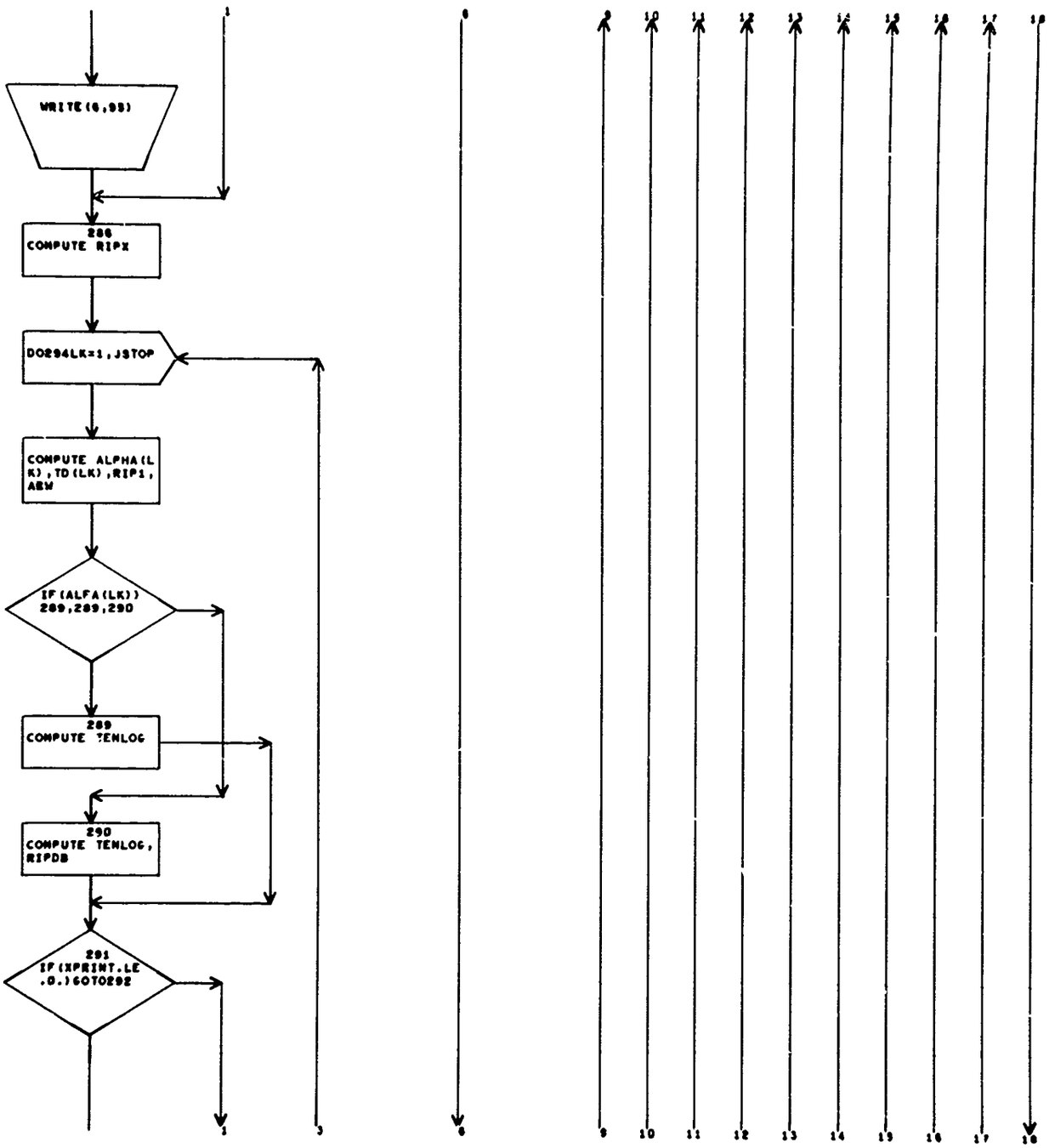
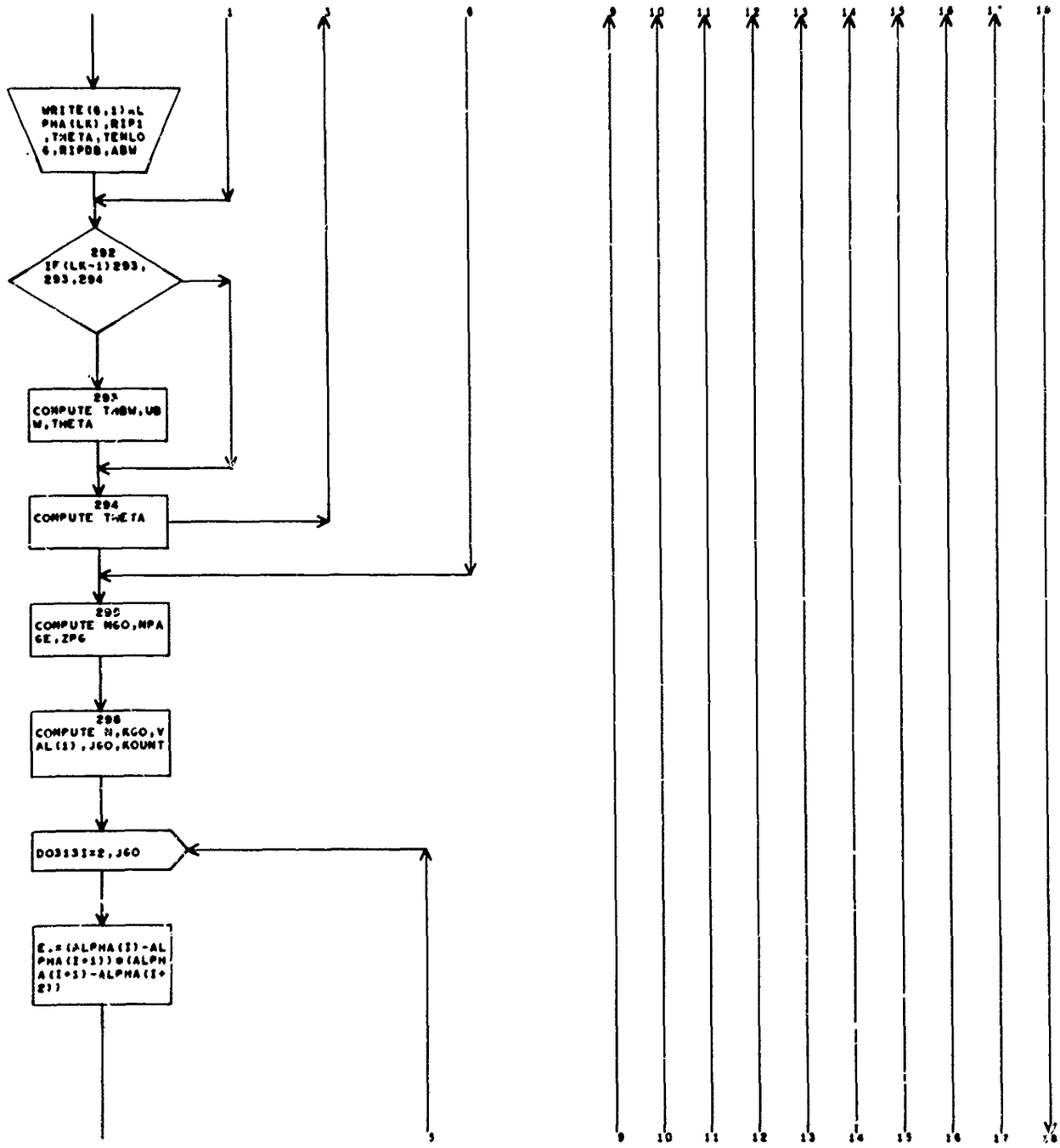
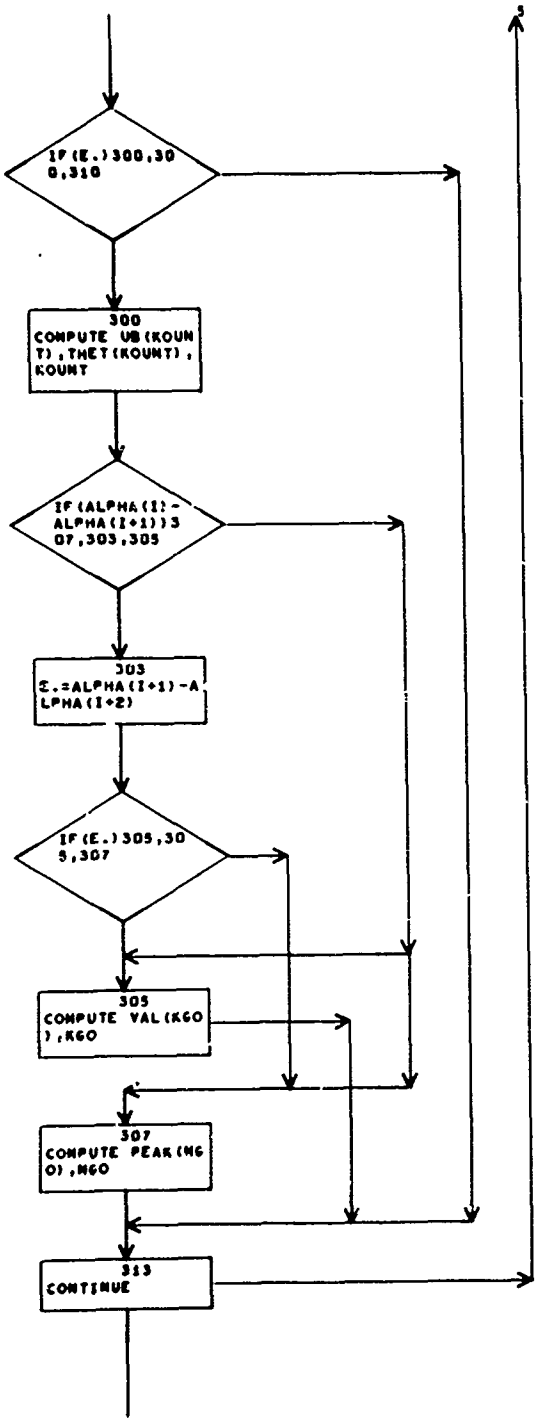
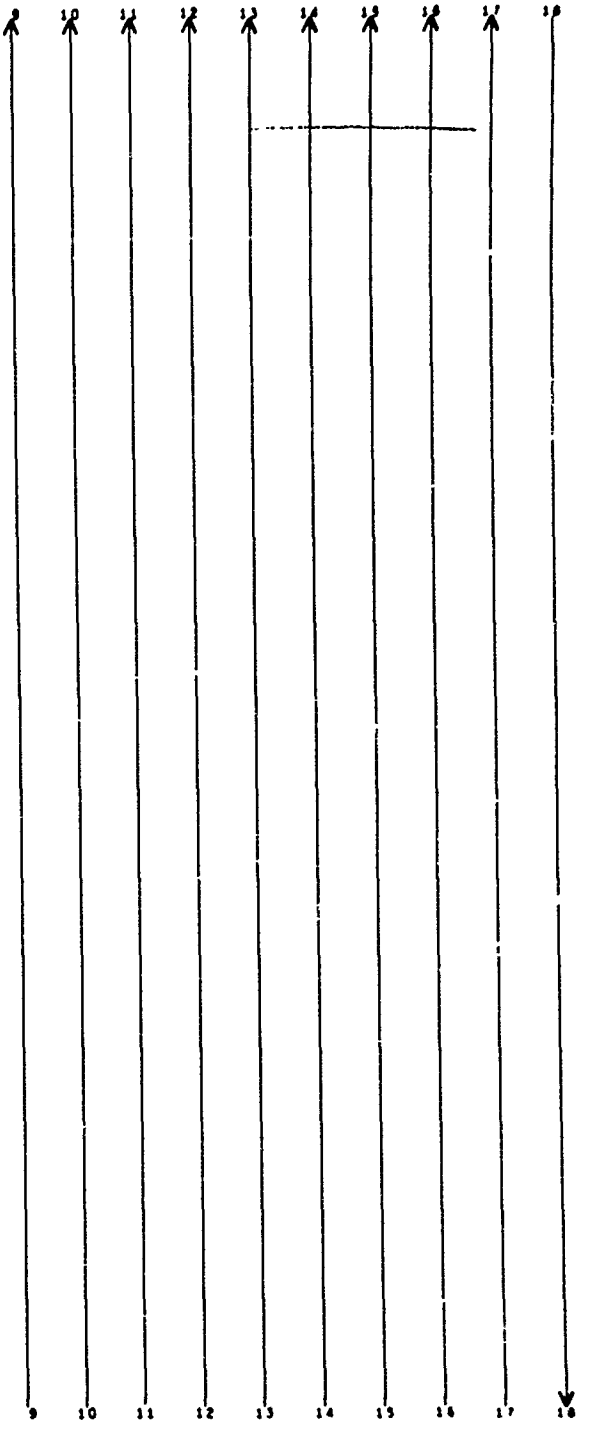

282
CONTINUE
COMPUTE IDEV
DO284NN=1,JSTOP
COMPUTE JK
DO284NN1=JK,L,J
STOP
284
COMPUTE ALFA(NN
)
IF(XPRINT.LE
.0.)GOTO286
WRITE(6,93)


WRITE(6,93)
286
COMPUTE RIPX
DO294LK=1,JSTOP
COMPUTE ALPHA(LK),TD(LK),RIP1,AEW
IF(ALFA(LK))289,289,290
289
COMPUTE TENLOG
290
COMPUTE TENLOG,RIPDB
291
IF(XPRINT.LE.0.)GOTO292


WRITE(6,1)AL
PHA(LR),RIP1
,THETA,TEMLO
G,RIPDB,ABW
292
IF(LR-1)293,
293,294
293
COMPUTE TABW,UB
W,THETA
294
COMPUTE THETA
295
COMPUTE NGO,NPA
GE,ZPG
296
COMPUTE N,KGO,V
AL(1),JGO,KOUNT
DO3131=2,JGO
E.=(ALPHA(I)-AL
PHA(I+1))*(ALPH
A(I+1)-ALPHA(I+
2))


IF(E.)300,30
0,310
300
COMPUTE UB(KOUN
T),THET(KOUNT),
KOUNT
IF(ALPHA(I)-
ALPHA(I+1))3
07,303,305
303
Σ.=ALPHA(I+1)-A
LPHA(I+2)
IF(E.)305,30
5,307
305
COMPUTE VAL(KGO
),KGO
307
COMPUTE PEAK(NG
O),NGO
313
CONTINUE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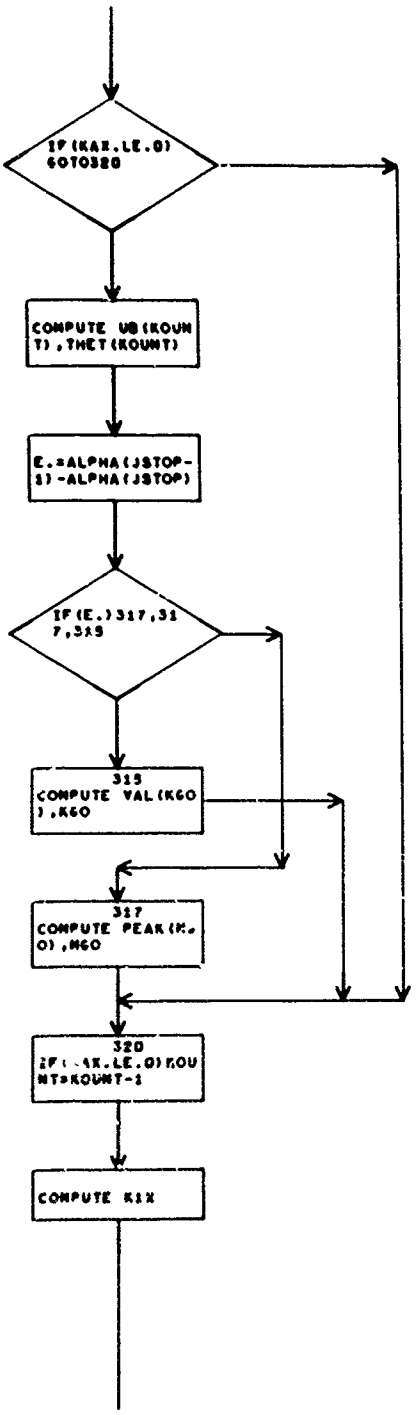
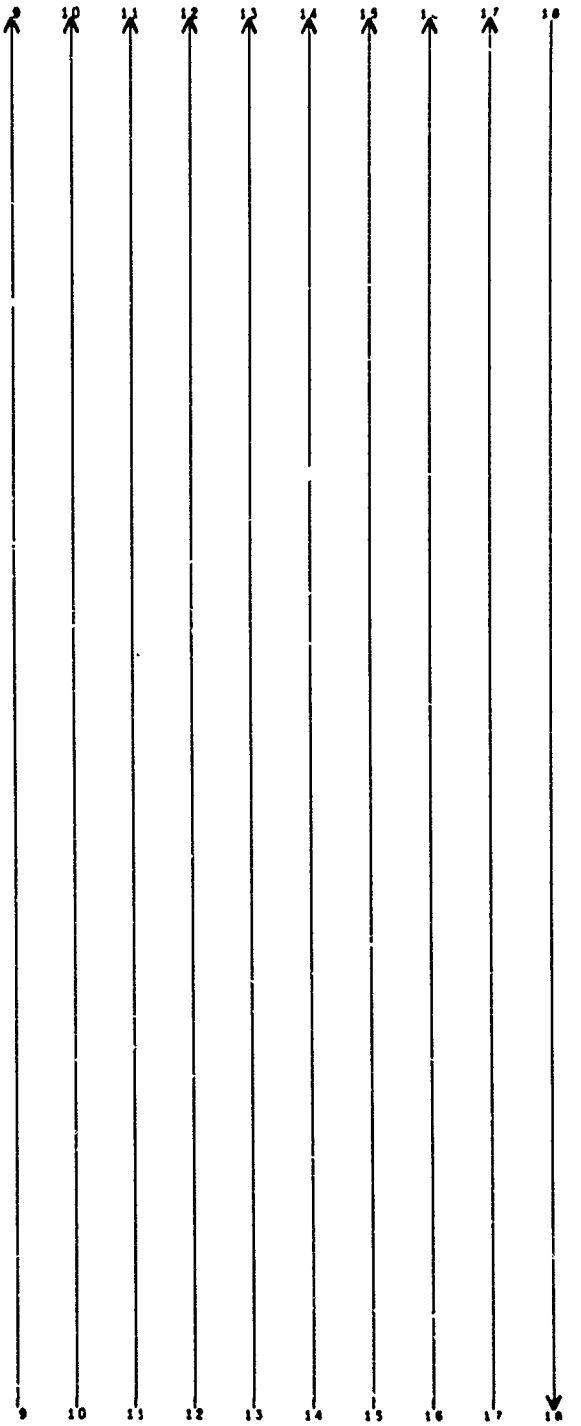

IF(KAX.LE.0)
GOTO320
COMPUTE UB(KOUN
T),THET(KOUNT)
E.=ALPHA(JSTOP-
1)-ALPHA(JSTOP)
IF(E.)317,31
7,315
315
COMPUTE VAL(KGO
),KGO
317
COMPUTE PEAK(K.
O),KGO
320
IF(-KX.LE.0)KOU
NT=KOUNT-1
COMPUTE KIX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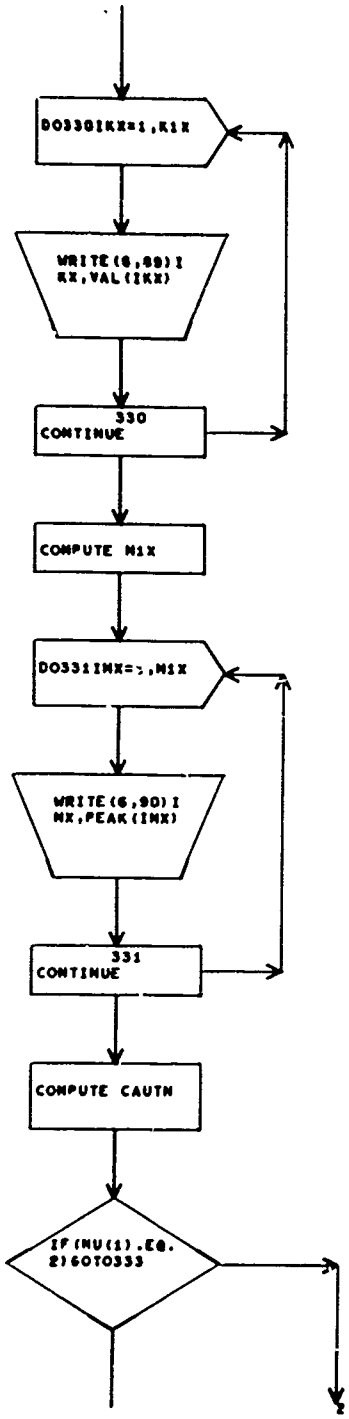
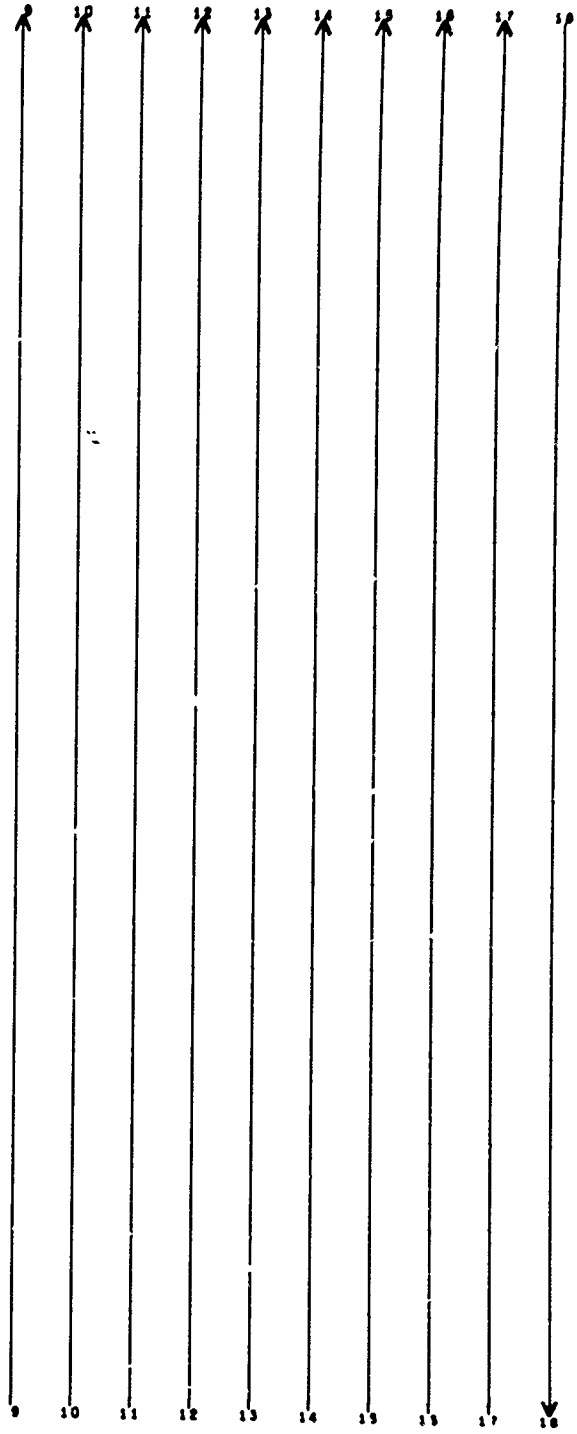

DO330IKX=1,K1X
WRITE(6,89)I
KX,VAL(IKX)
330
CONTINUE
COMPUTE M1X
DO331IMX=1,M1X
WRITE(6,90)I
MX,PEAK(IMX)
331
CONTINUE
COMPUTE CAUTN
IF(NU(1).EQ.
2)GOTO333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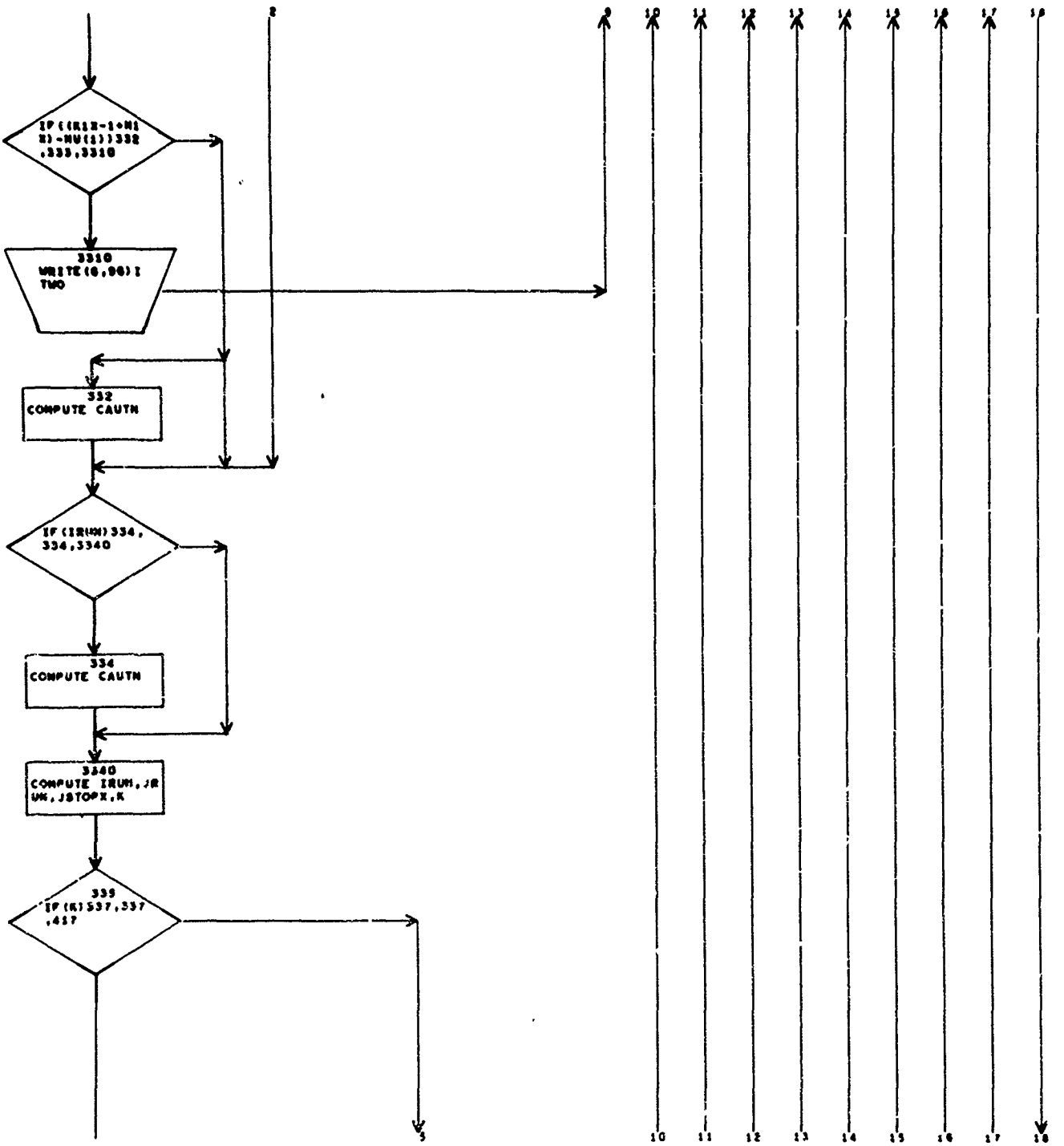
IF((R1I-1+N1
I)-NU(I))332
,333,3310
3310
WRITE(6,90)I
TWO
332
COMPUTE CAUTN
IF(IRUN)334,
334,3340
334
COMPUTE CAUTN
3340
COMPUTE IRUN,JR
UN,JSTOPX,K
335
IF(K)537,537
,417
2
9
10
11
12
13
14
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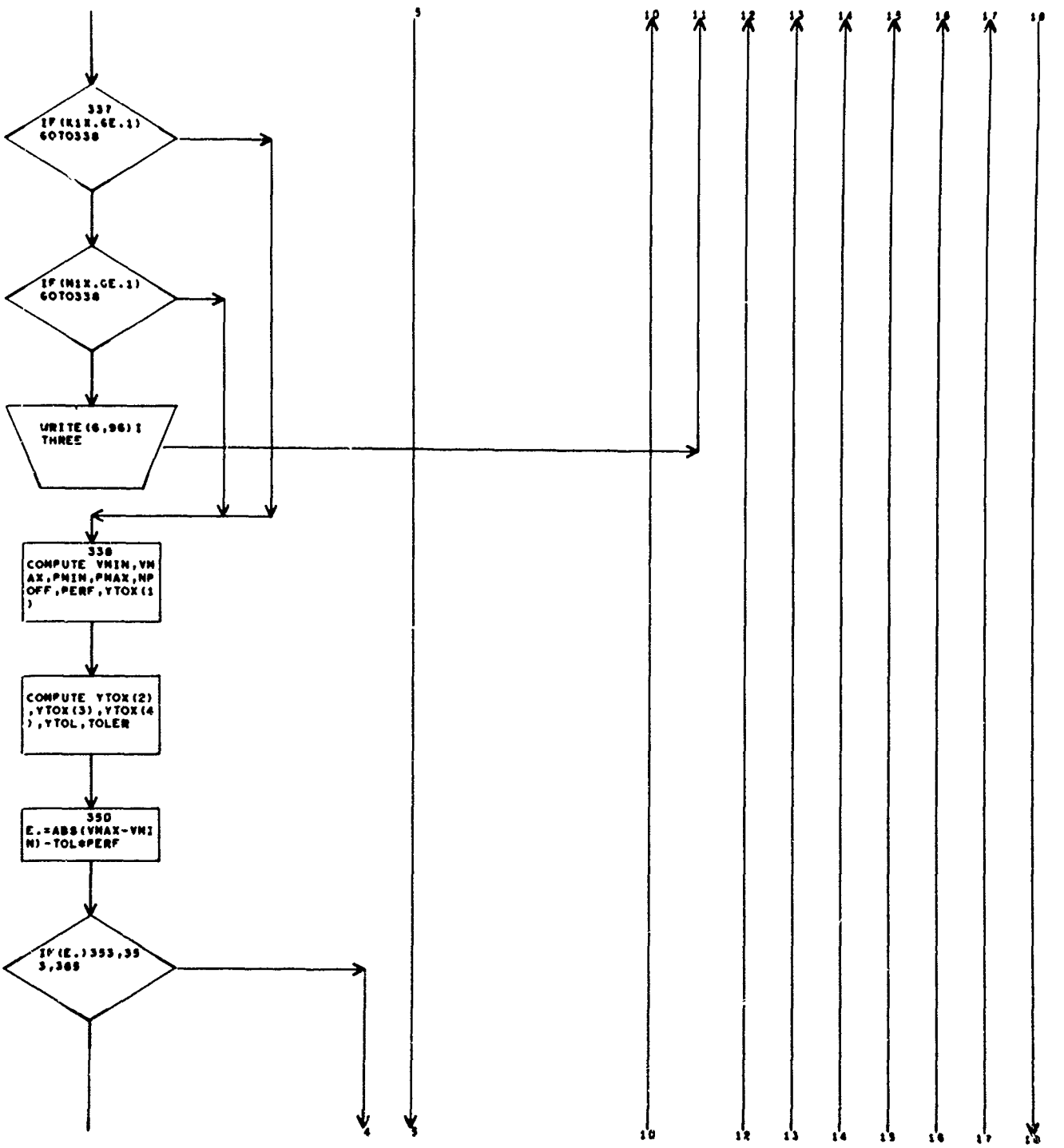
5


337
IF(KIX.GE.1)
GOTO338
IF(NIX.GE.1)
GOTO338
WRITE(6,96)
THREE
338
COMPUTE VMIN,VM
AX,PMIN,PMAX,NP
OFF,PERF,YTOX(1
)
COMPUTE YTOX(2)
,YTOX(3),YTOX(4
),YTOL,TOLER
350
E.=ABS(VMAX-VMI
N)-TOL*PERF
IF(E.)353,35
3,368
5
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11
12
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14
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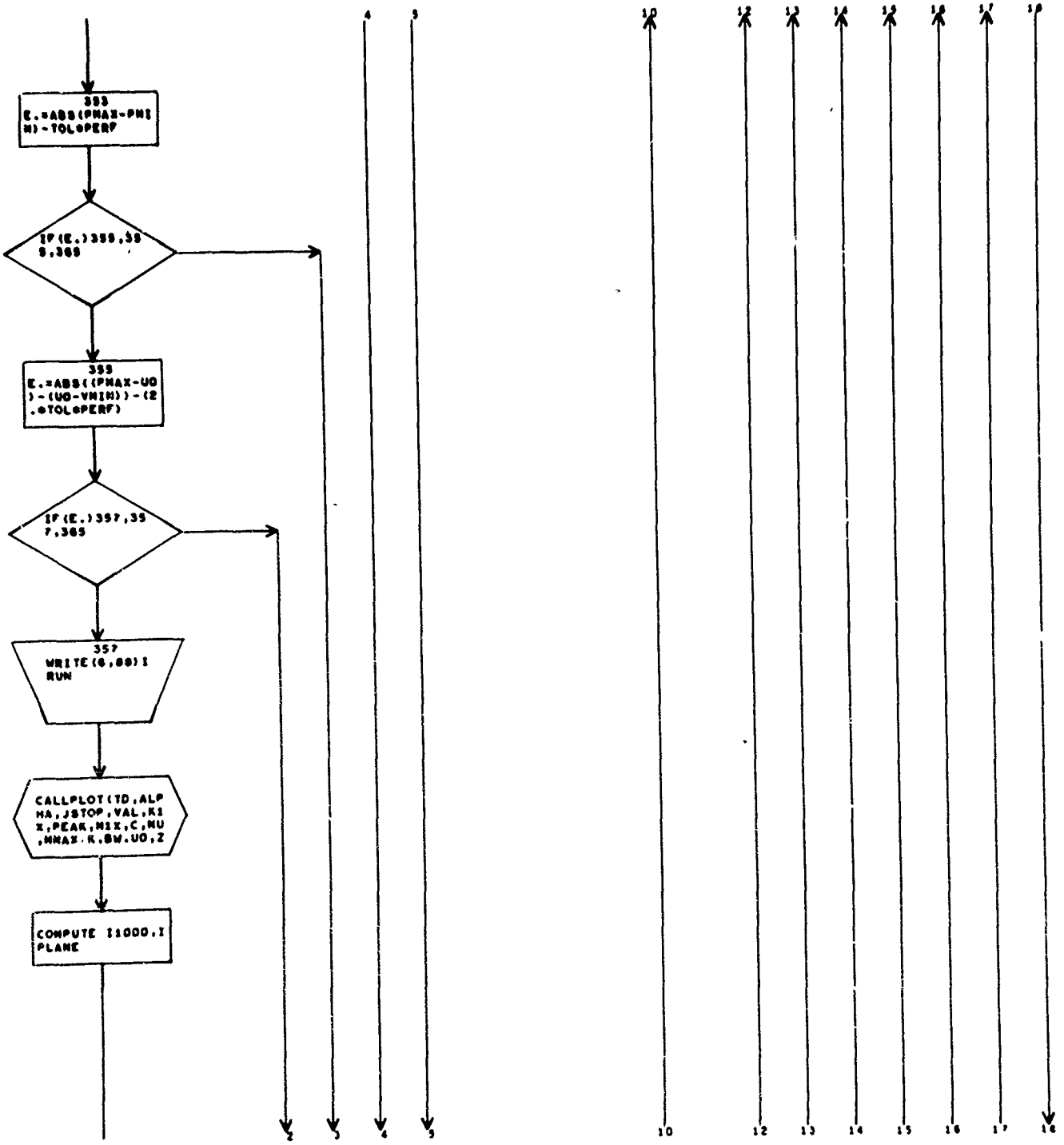
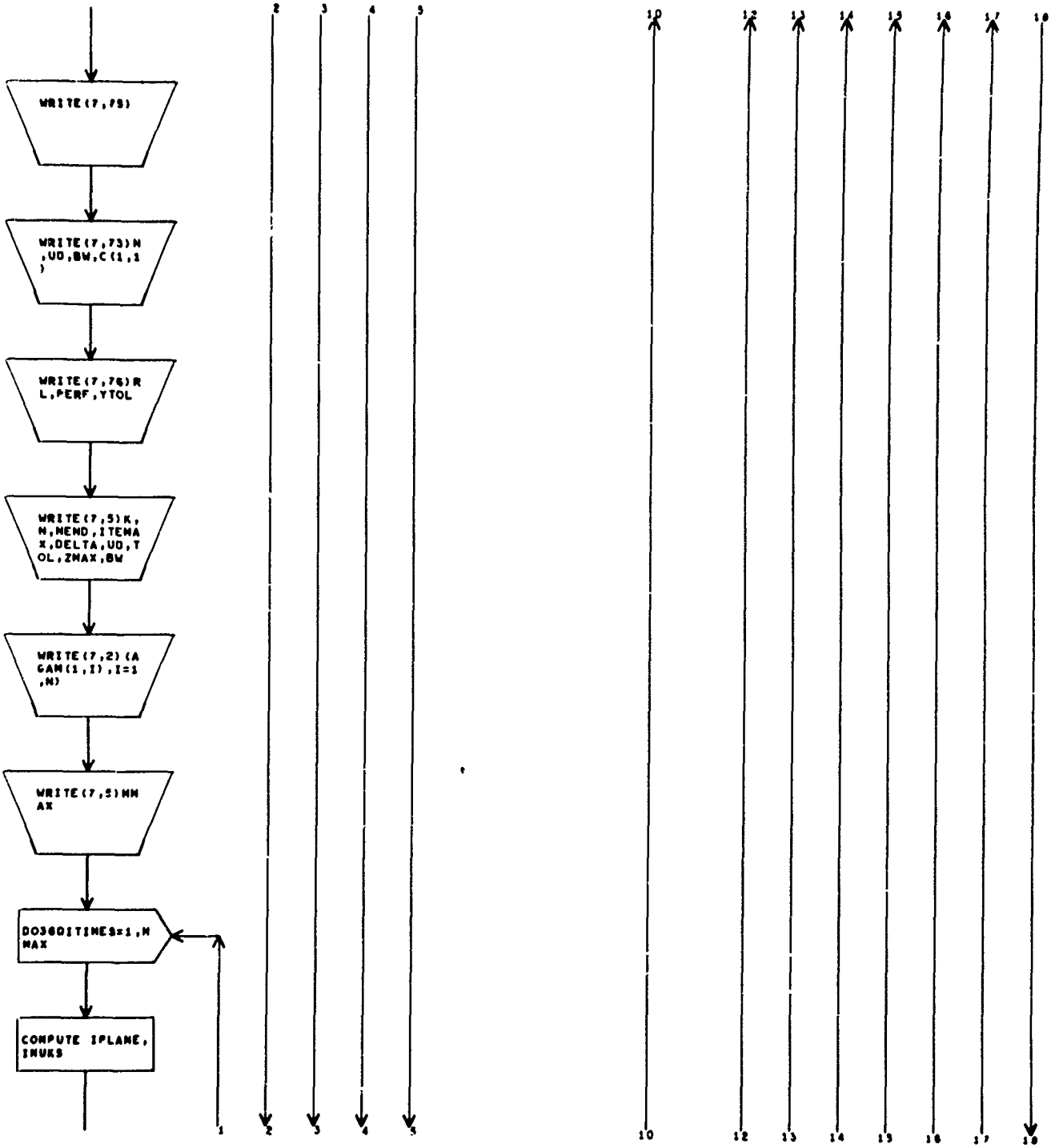
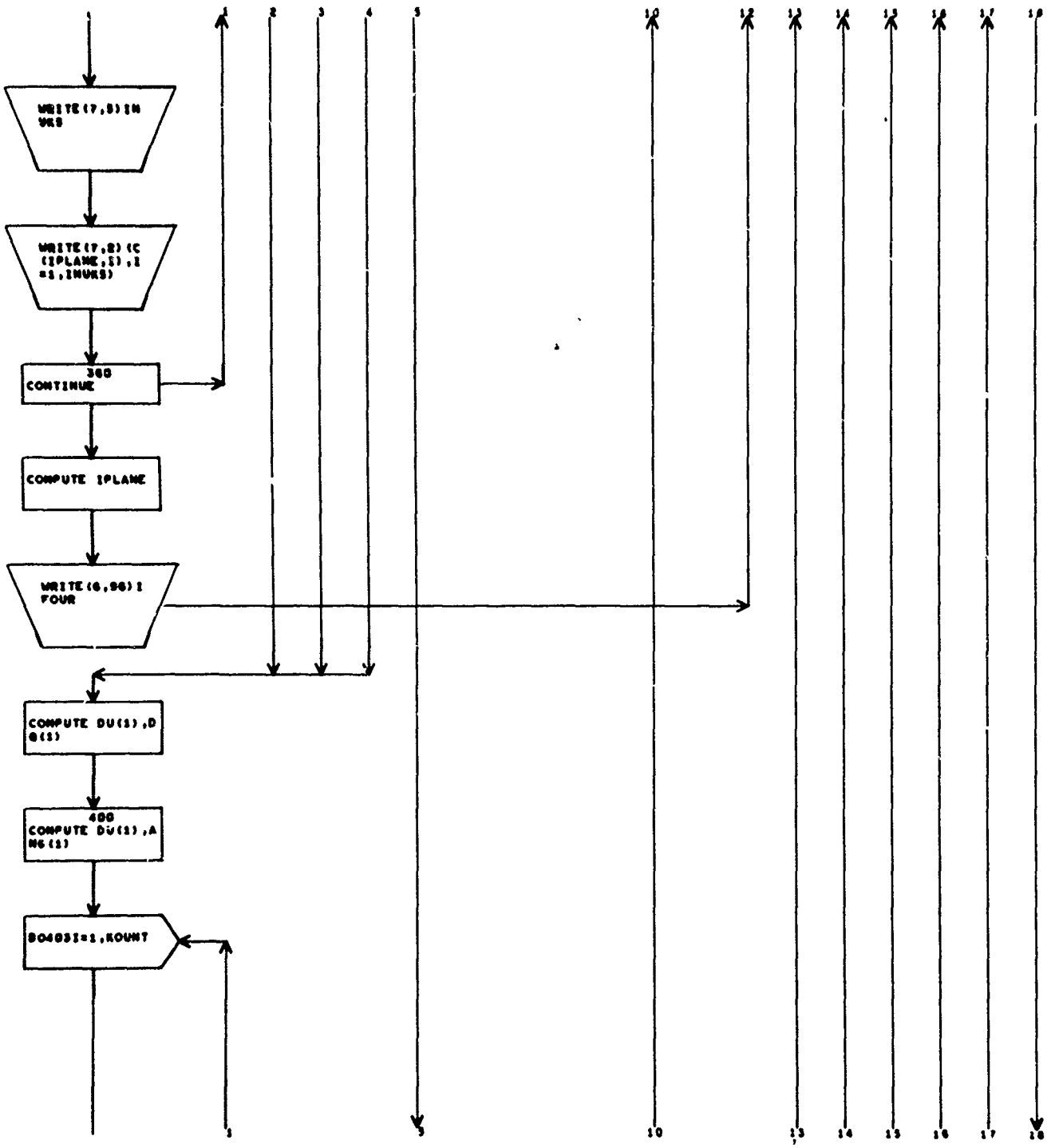
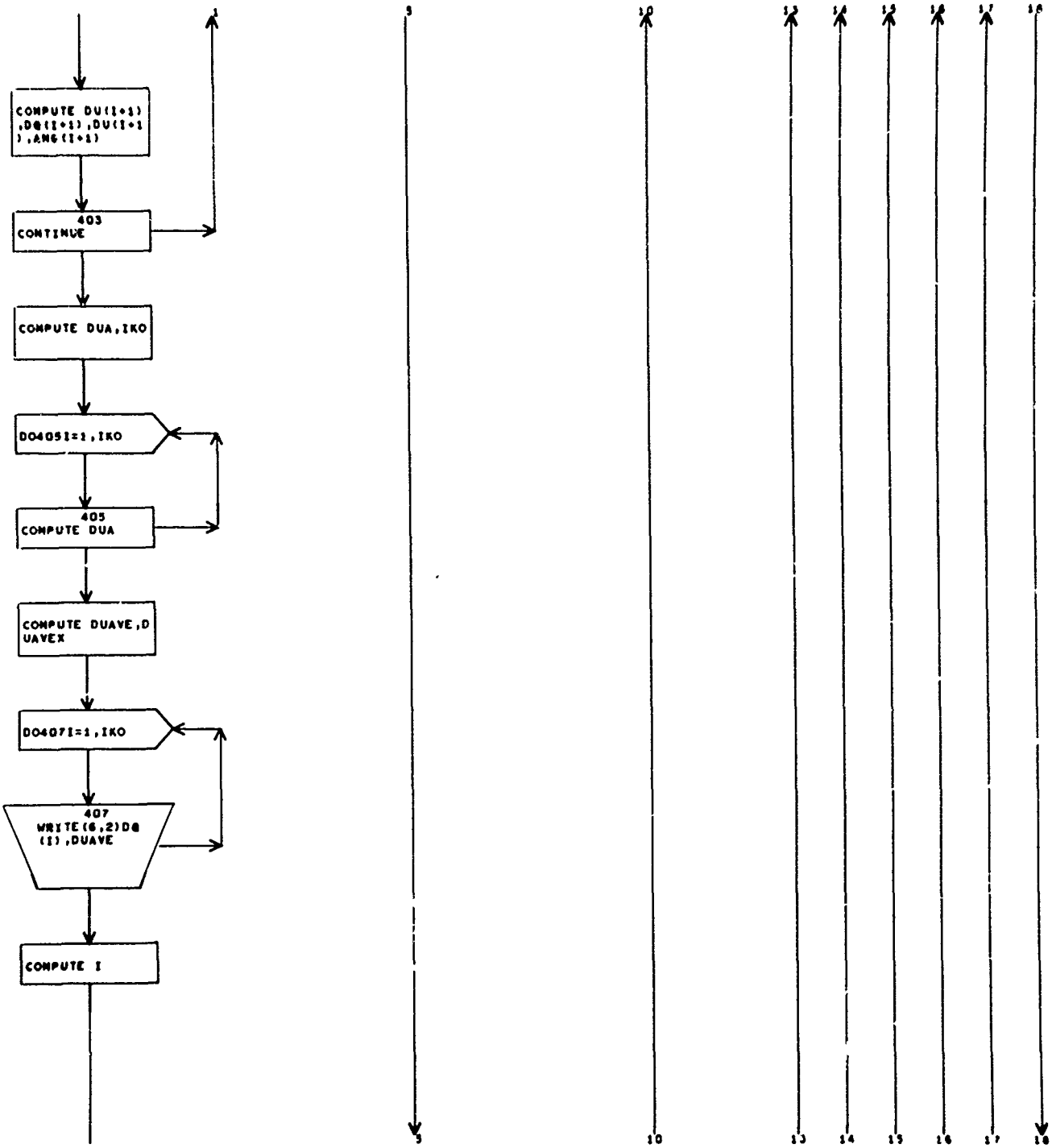
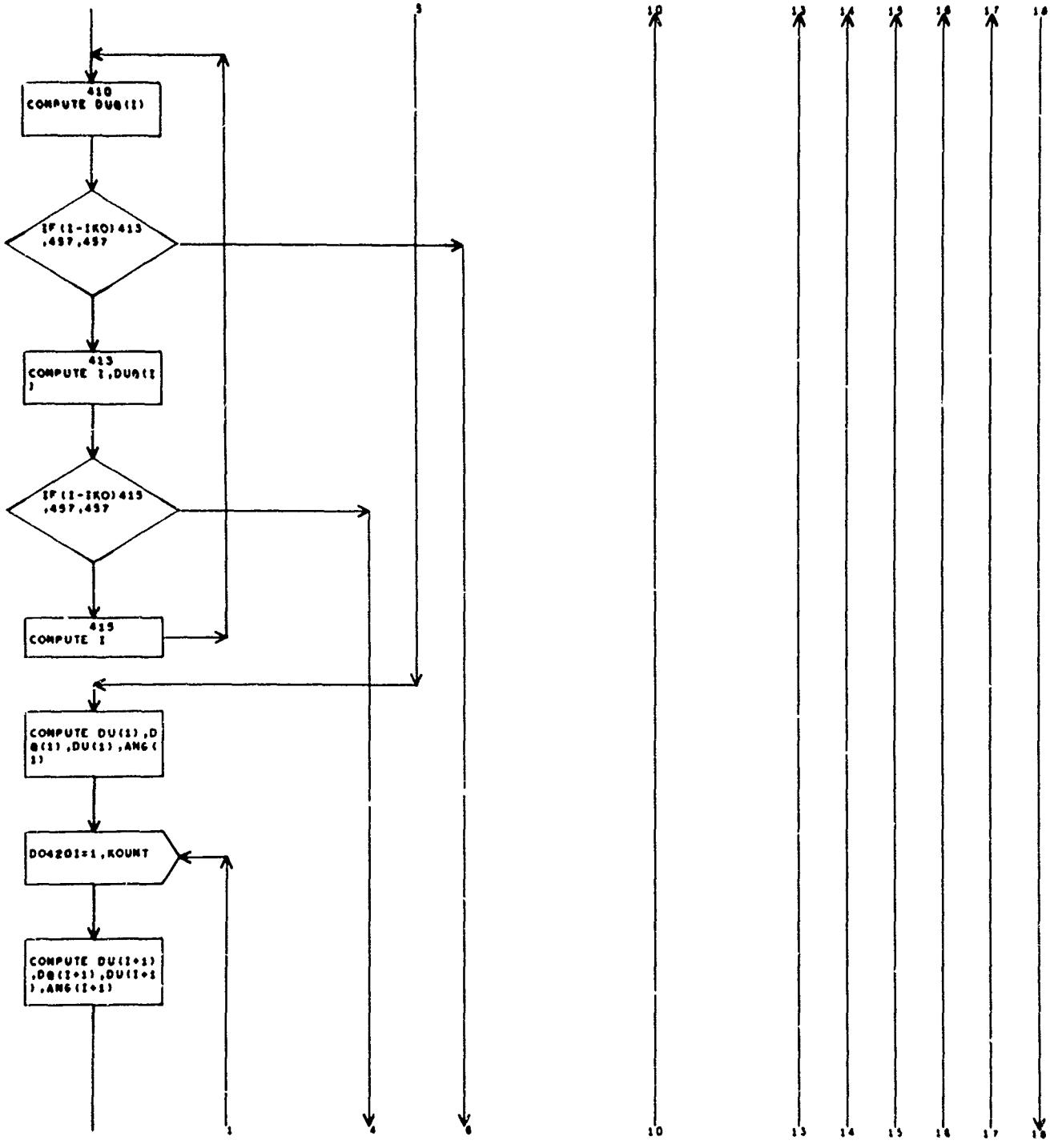
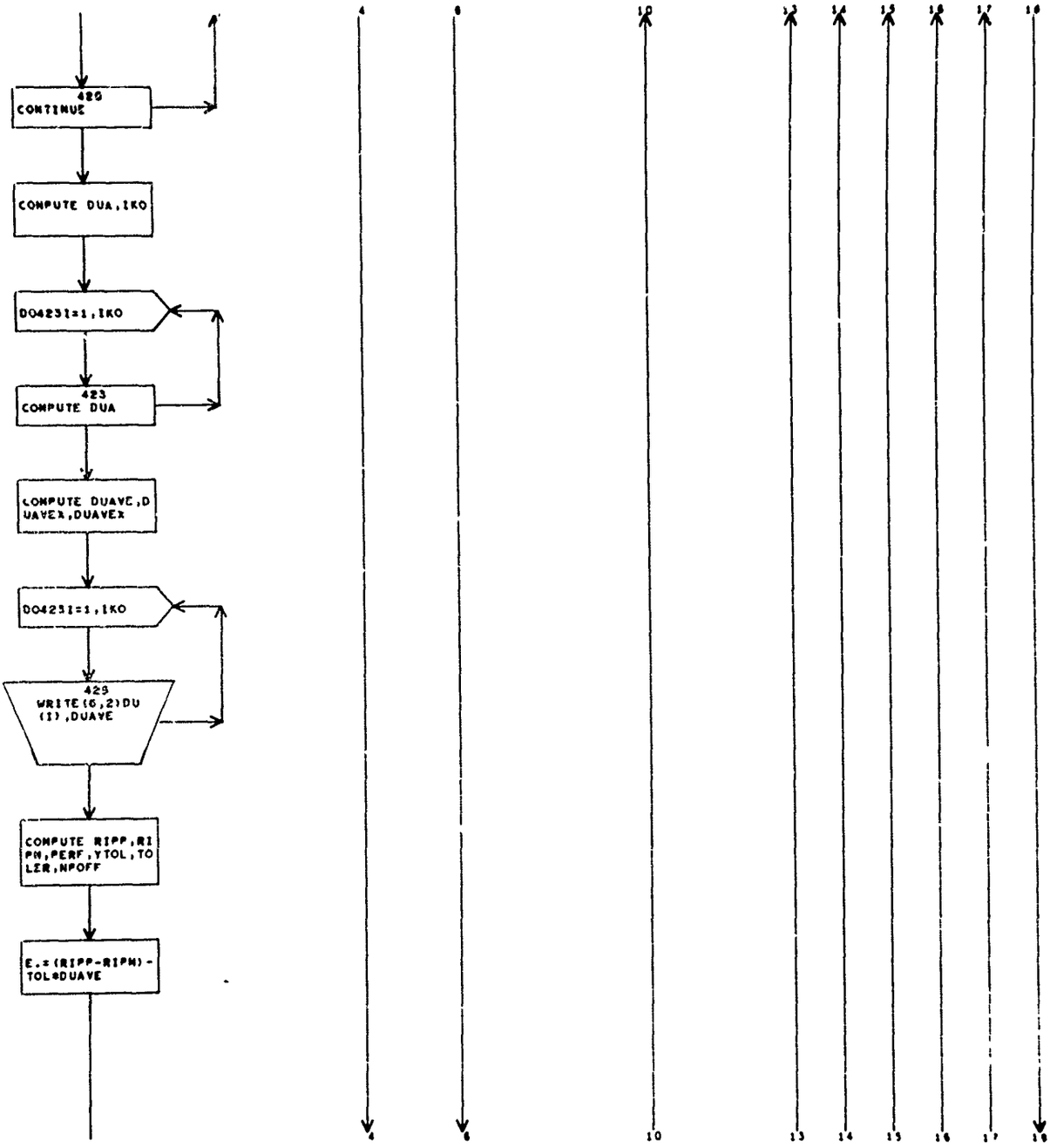

355
E.=ABS(PMAX-PMI
N)-TOL*PERF
IF(E.)359,358
8,359
359
E.=ABS((PMAX-UO
)-(UO-VMIN))-(2
.*TOL*PERF)
IF(E.)357,35
7,365
357
WRITE(6,88)I
RUN
CALLPLOT(TD,ALP
HA,JSTOP,VAL,KI
X,PEAK,MIX,C,NU
,MMAX,R,BW,UO,Z
COMPUTE I1000,I
PLANE

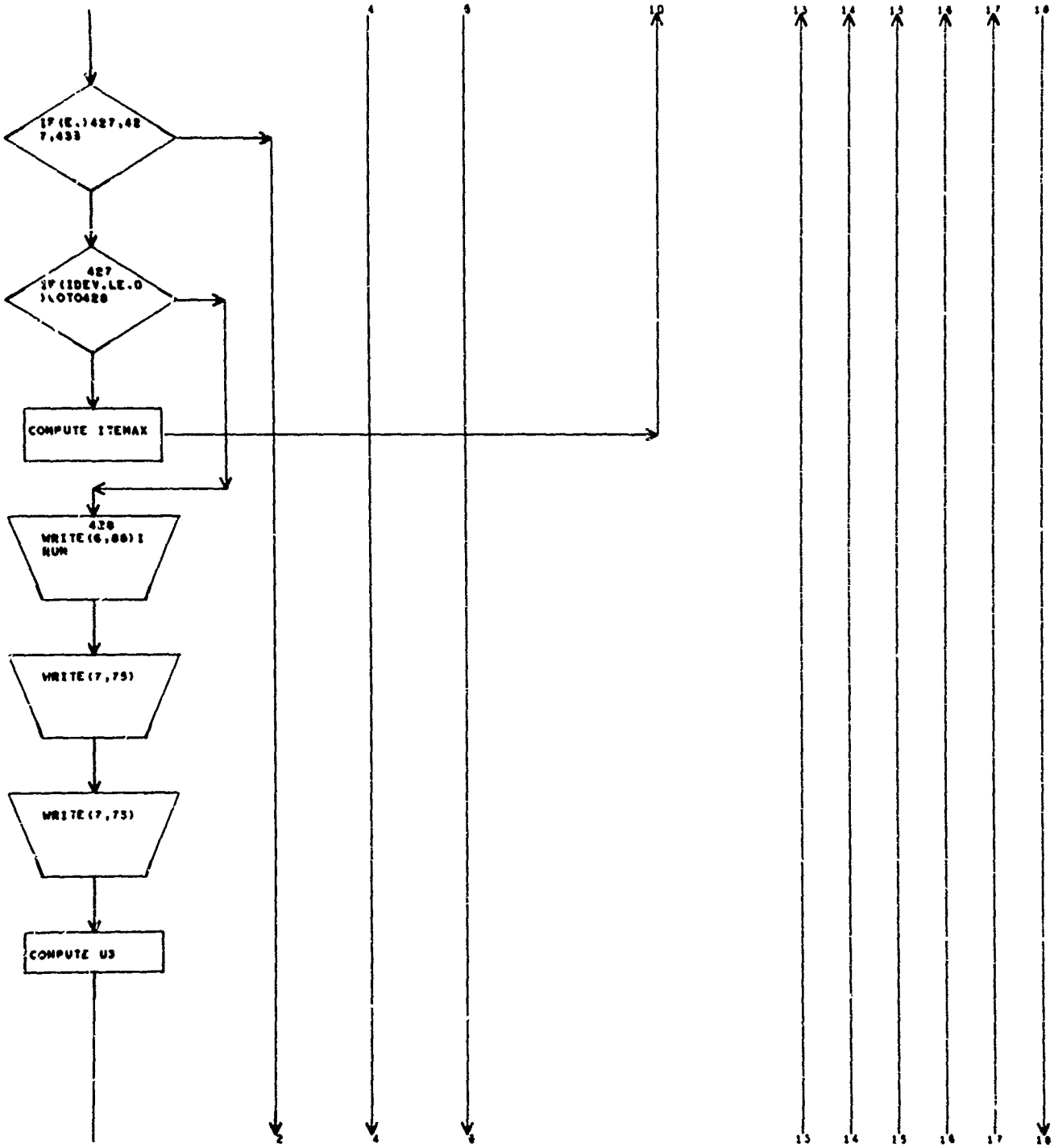

WRITE(7,79)
WRITE(7,73)N,UD,BW,C(1,1)
WRITE(7,76)RL,PERF,YTOL
WRITE(7,5)K,N,NEND,ITEMAX,DELTA,UD,TOL,ZMAX,BW
WRITE(7,2)(AGAM(1,I),I=1,N)
WRITE(7,5)MMAX
DO360ITIMES=1,MMAX
COMPUTE IPLANE, INUKS
1
2
3
4
5
10
12
13
14
15
16
17
18

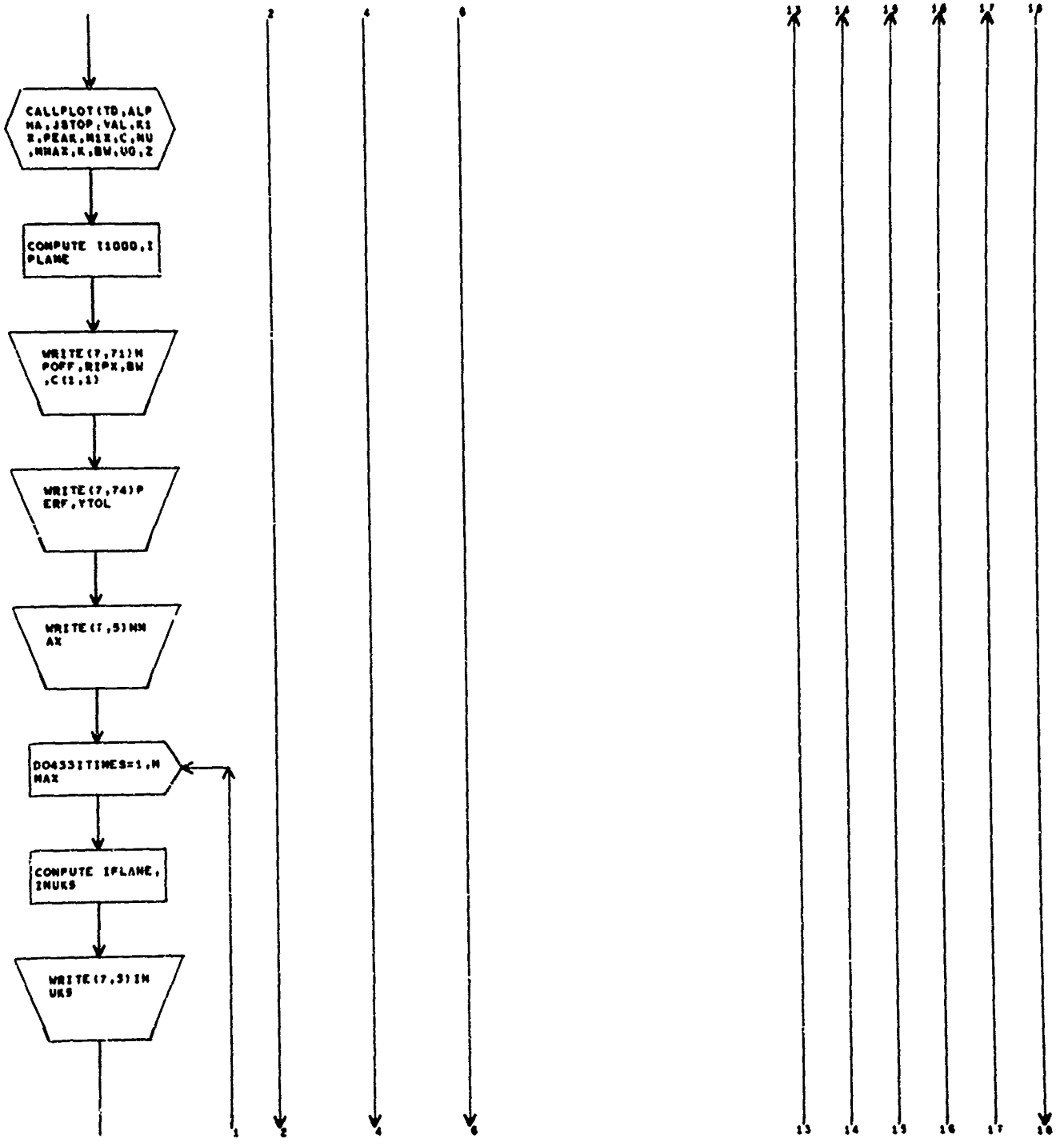

WRITE(7,8)IN
WRITE(7,8)(C
(IPLANE,I),I
=1,INUMS)
360
CONTINUE
COMPUTE IPLANE
WRITE(6,96)I
FOUR
COMPUTE DU(I),D
G(I)
400
COMPUTE DU(I),A
MG(I)
DO403I=1,KOUNT

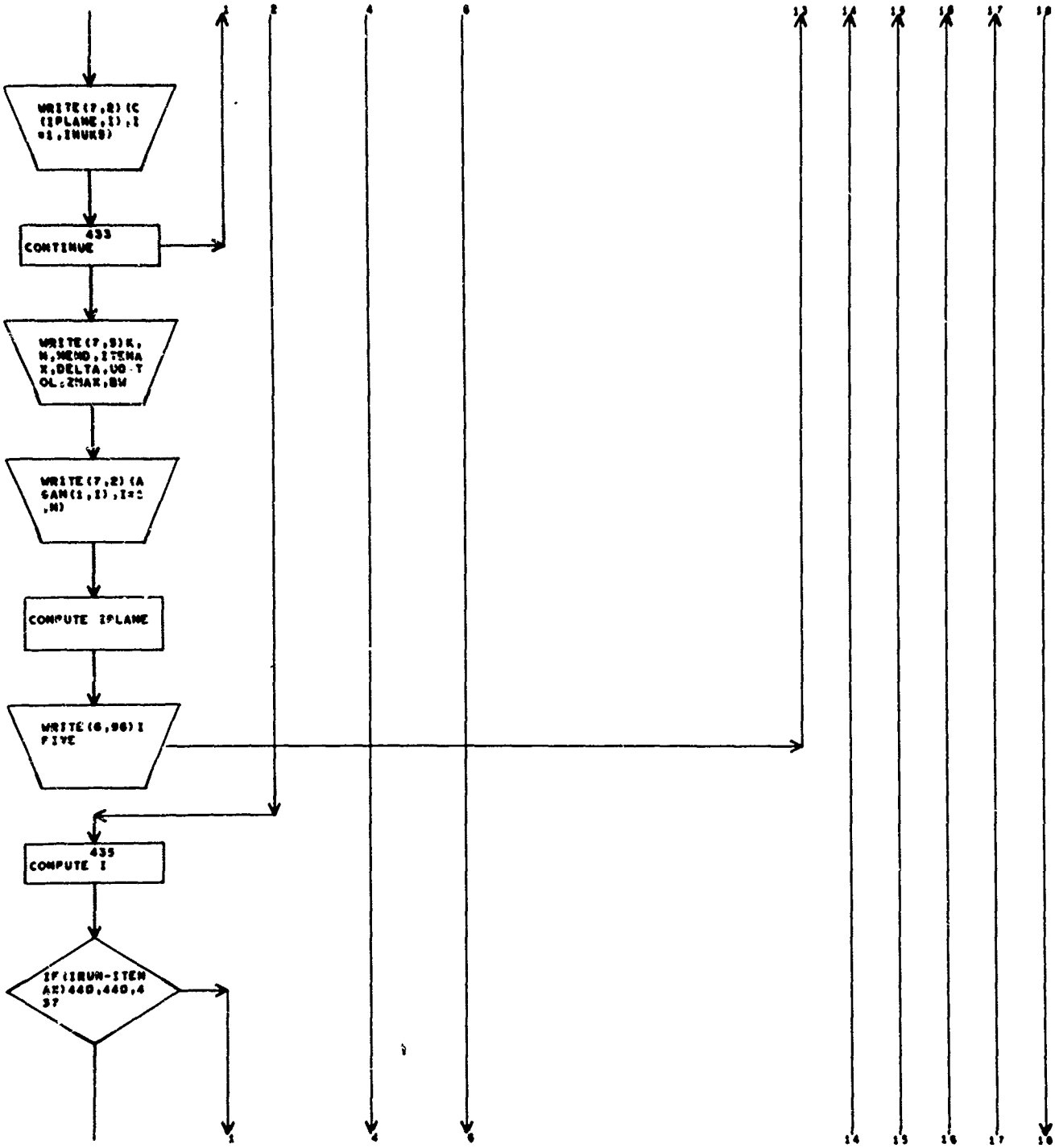

COMPUTE DU(I+1),D@(I+1),DV(I+1),ANG(I+1)
403 CONTINUE
COMPUTE DUA,IKO
DO405I=1,IKO
405 COMPUTE DUA
COMPUTE DUAVE,DUAVEX
DO407I=1,IKO
407 WRITE(6,2)D@(I),DUAVE
COMPUTE I

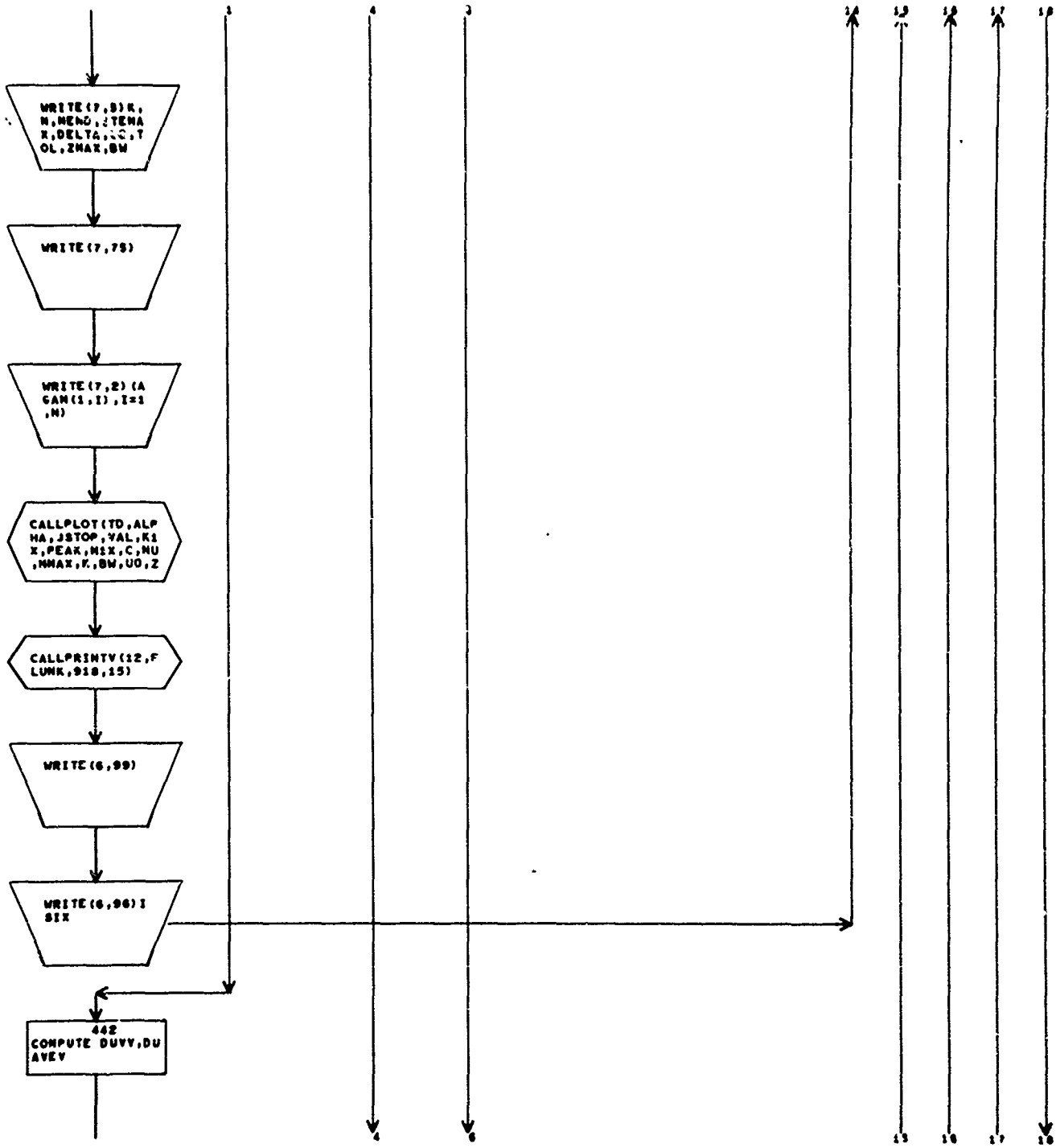

410
COMPUTE DU@(I)
IF(I-IKO)413
,457,457
413
COMPUTE I,DU@(I
)
IF(I-IKO)413
,457,457
415
COMPUTE I
COMPUTE DU(I),D
@(I),DU(I),ANG(
I)
DO420I=1,KOUNT
COMPUTE DU(I+1)
,D@(I+1),DU(I+1
),ANG(I+1)
5
10
13
14
15
16
17
18
1
4
6
10
13
14
15
16
17
18

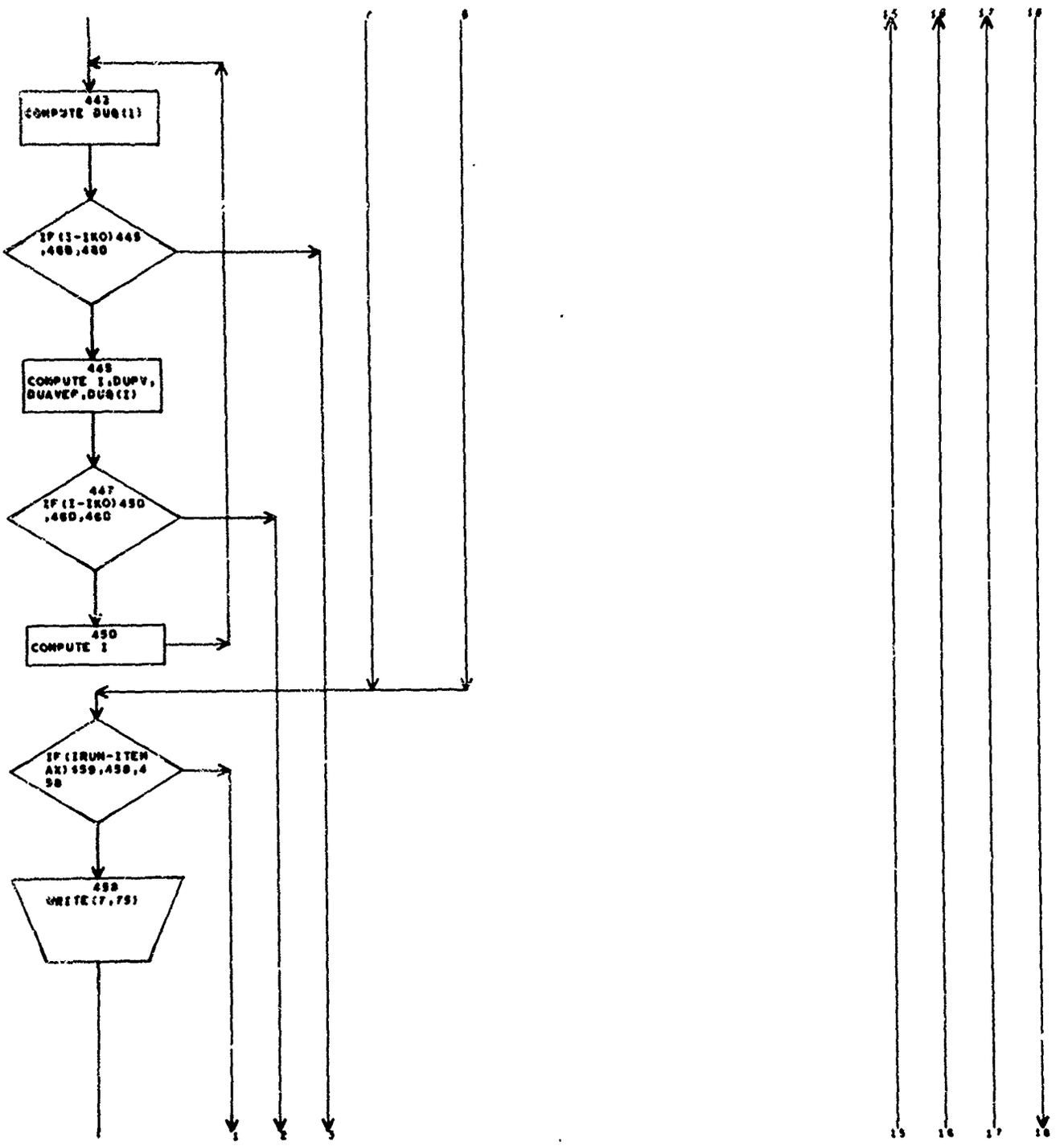

4
6
10
13
14
15
16
17
18
420
CONTINUE
COMPUTE DUA,IKO
DO4231=1,IKO
423
COMPUTE DUA
COMPUTE DUAVE,DUAVEX,DUAVEX
DO4231=1,IKO
429
WRITE(6,2)DU(I),DUAVE
COMPUTE RIPP,RIPM,PERF,YTOL,TOLER,NPOFF
E.=(RIPP-RIPM)-TOL*DUAVE
4
6
10
13
14
15
16
17
18

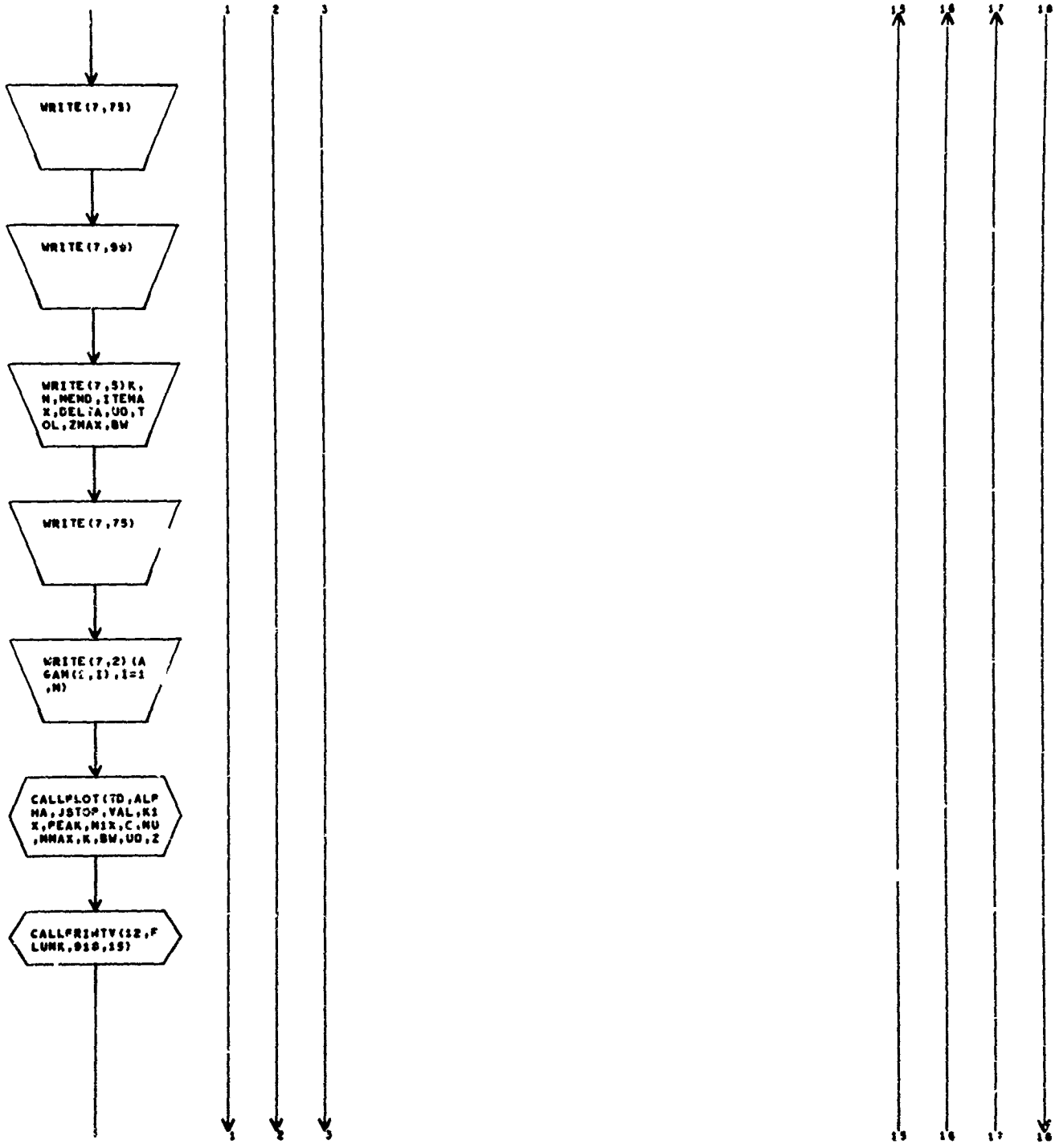

IF(E.)427,428,433
427
IF(IDEV.LE.0)GOTO428
COMPUTE ITEMAX
428
WRITE(6,80)I RUN
WRITE(7,75)
WRITE(7,75)
COMPUTE U3
2
4
6
10
13
14
15
16
17
18

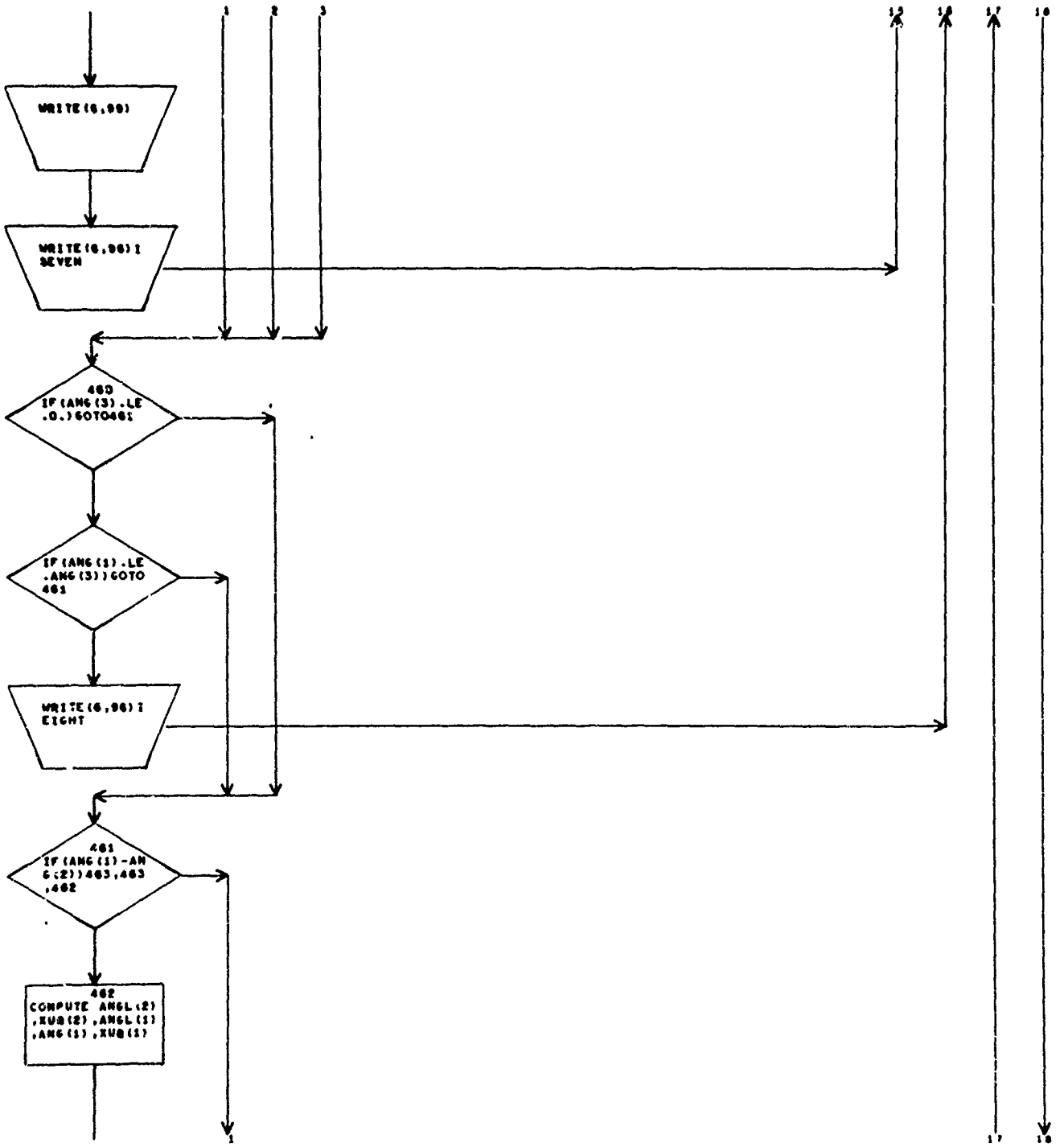

CALLPLOT(TD,ALPHA,JSTOP,VAL,RIR,PEAK,MIX,C,NU,MMAX,K,BW,UO,Z
COMPUTE (1000,IPLANE
WRITE(7,71)HPOFF,RIPK,BW,C(1,1)
WRITE(7,74)PERF,YTOL
WRITE(7,5)MMAX
DO433ITIMES=1,MMAX
COMPUTE IPLANE, INUKS
WRITE(7,5)INUKS
1
2
4
6
13
14
15
16
17
18

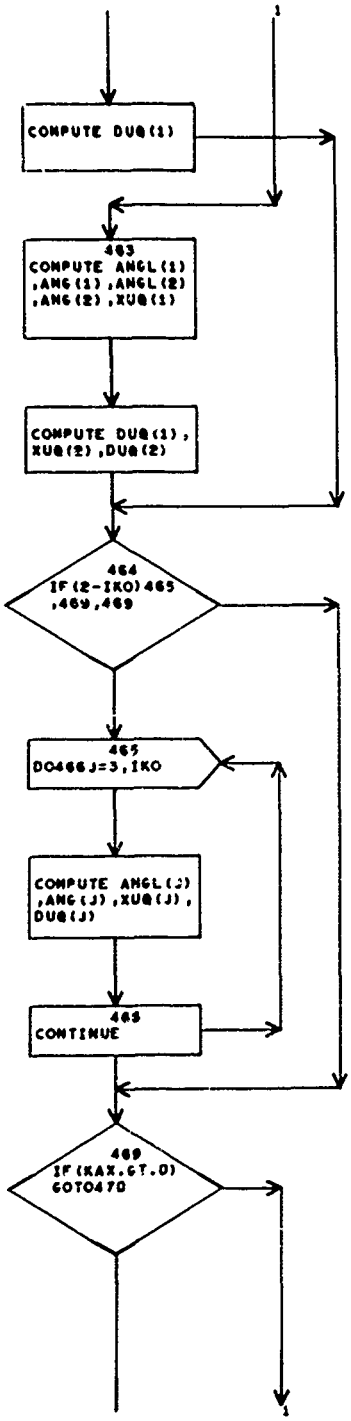

WRITE(7,2)((C
(IPLANE,I),I
=1,INUMS)
433
CONTINUE
WRITE(7,9)K,
M,MEMD,ITENA
X,DELTA,VO-T
OL,ZMAX,BW
WRITE(7,2)(A
SAN(1,I),I=1
,M)
COMPUTE IPLANE
WRITE(6,96)I
FIVE
435
COMPUTE I
IF(INUM-ITEN
AX)440,440,4
37

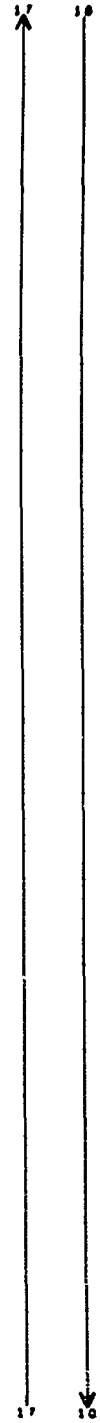

WRITE(7,8)K,
M,MEND,ITEMA
X,DELTA,TC,T
OL,ZMAX,BW
WRITE(7,79)
WRITE(7,2)(A
GAM(1,I),I=1
,M)
CALLPLOT(TD,ALP
HA,JSTOP,VAL,K1
X,PEAK,MIX,C,NU
,NMAX,K,BW,UO,Z
CALLPRINTV(12,F
LUNK,918,15)
WRITE(6,99)
WRITE(6,96)I
SIX
442
COMPUTE DUVV,DU
AVEV

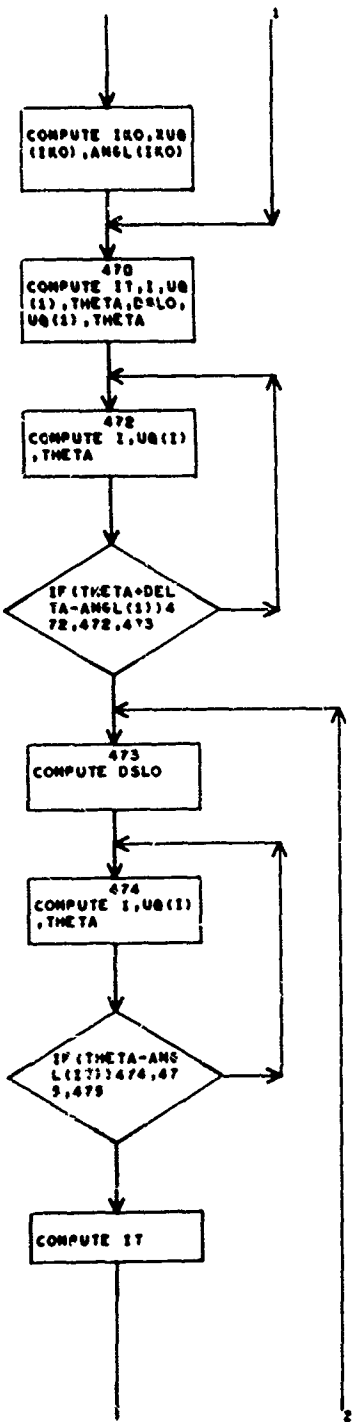

443
COMPUTE DUB(I)
IF(I-IKO)445
,460,460
445
COMPUTE I,DUPV,
DUAVEP,DUB(I)
447
IF(I-IKO)450
,460,460
450
COMPUTE I
IF(IRUN-ITEM
AX)459,458,4
58
458
WRITE(7,75)
1
2
3
15
16
17
18

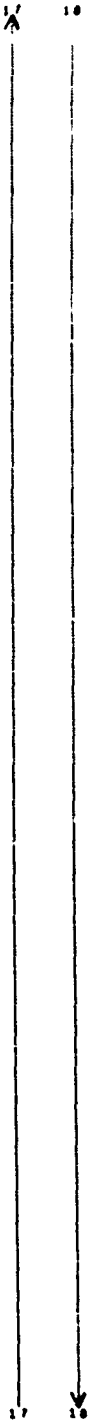

WRITE(7,75)
WRITE(7,99)
WRITE(7,5)K,
N,MEND,ITEMA
X,DELTA,UO,T
OL,ZMAX,BW
WRITE(7,75)
WRITE(7,2)(A
GAM(I,I),I=1
,N)
CALLPLOT(TD,ALP
HA,JSTOP,VAL,K1
X,PEAK,MIX,C,NU
,MMAX,K,BW,UO,Z
CALLPRINTV(12,F
LUNK,910,15)
1
2
3
15
16
17
18

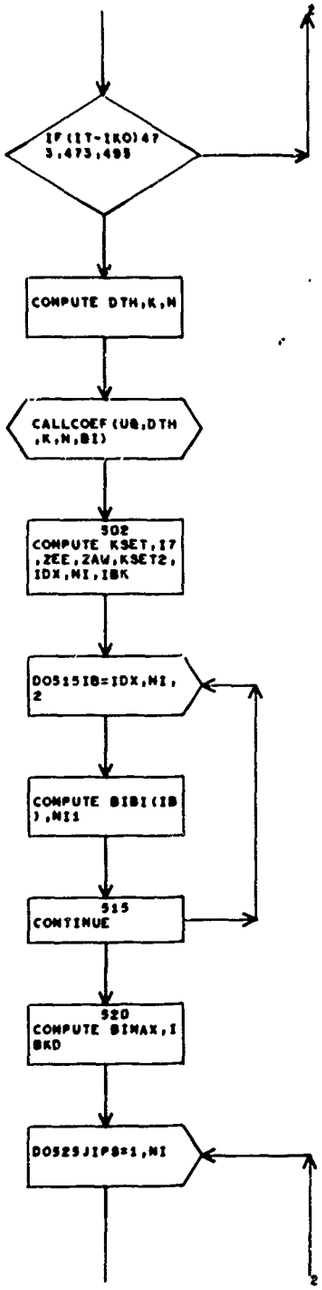

1
2
3
19
18
17
16
WRITE(6,99)
WRITE(6,98) I
SEVEN
460
IF(ANG(3).LE
.0.)GOTO461
IF(ANG(1).LE
.ANG(3))GOTO
461
WRITE(6,98) I
EIGHT
461
IF(ANG(1)-AN
G(2))463,463
,462
462
COMPUTE ANGL(2)
,XUB(2),ANGL(1)
,ANG(1),XUB(1)
1
17
18

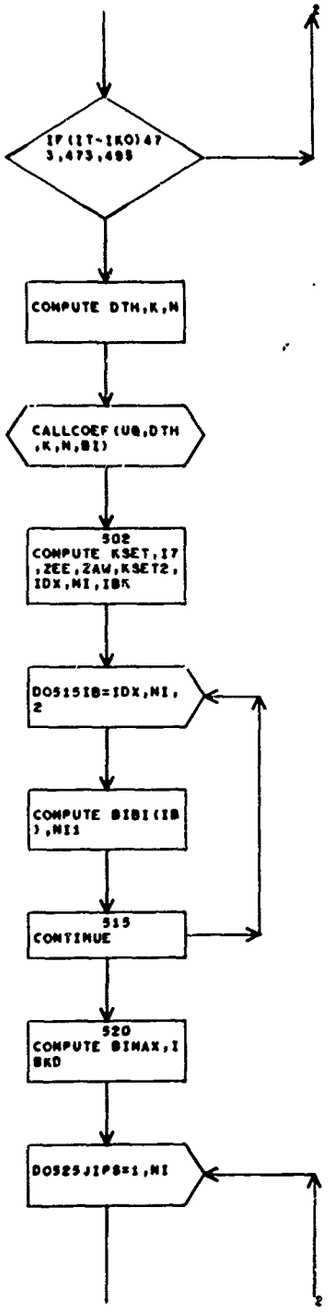

1
COMPUTE DUB(1)
463
COMPUTE ANGL(1)
,ANG(1),ANGL(2)
,ANG(2),XUB(1)
COMPUTE DUB(1),
XUB(2),DUB(2)
464
IF(2-IKO)465
,469,469
465
DO466J=3,IKO
COMPUTE ANGL(J)
,ANG(J),XUB(J),
DUB(J)
466
CONTINUE
469
IF(KAX.GT.0)
GOTO470
1

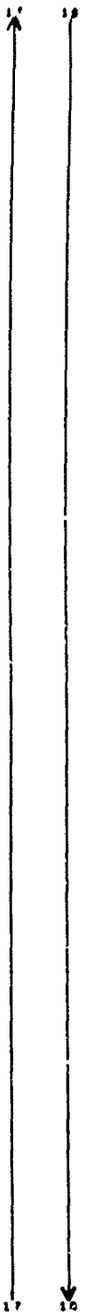

17
18
17
18

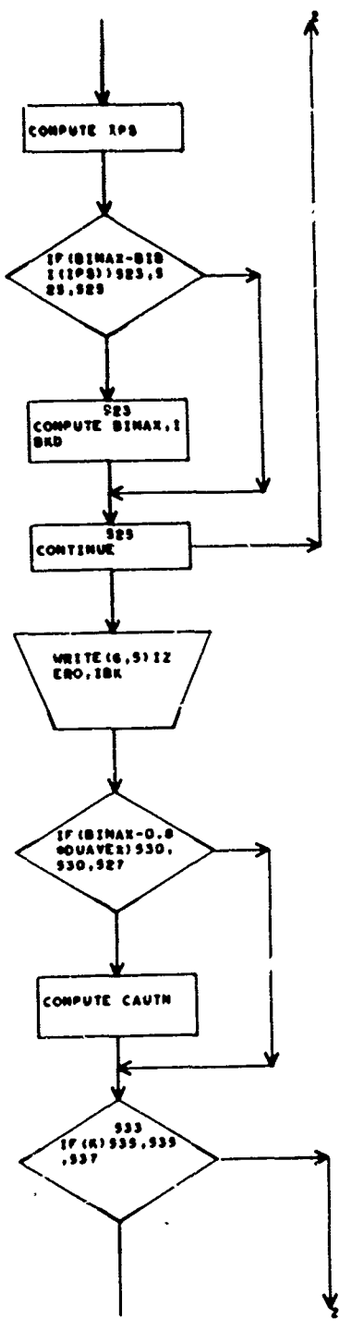

1
COMPUTE IKO,ZUB (IKO),ANGL(IKO)
470
COMPUTE IT,I,UB (1),THETA,DSLO, UB(I),THETA
472
COMPUTE I,UB(I) ,THETA
IF(THETA+DEL TA-ANGL(1))4 72,472,473
473
COMPUTE DSLO
474
COMPUTE I,UB(I) ,THETA
IF(THETA-ANG L(IT))474,47 5,475
COMPUTE IT
2

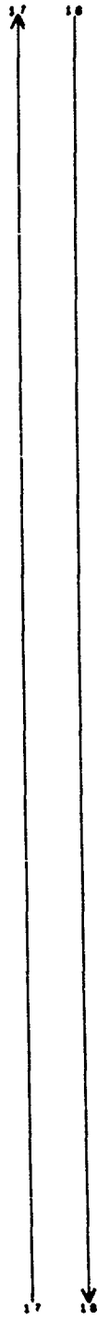

17
18
17
18

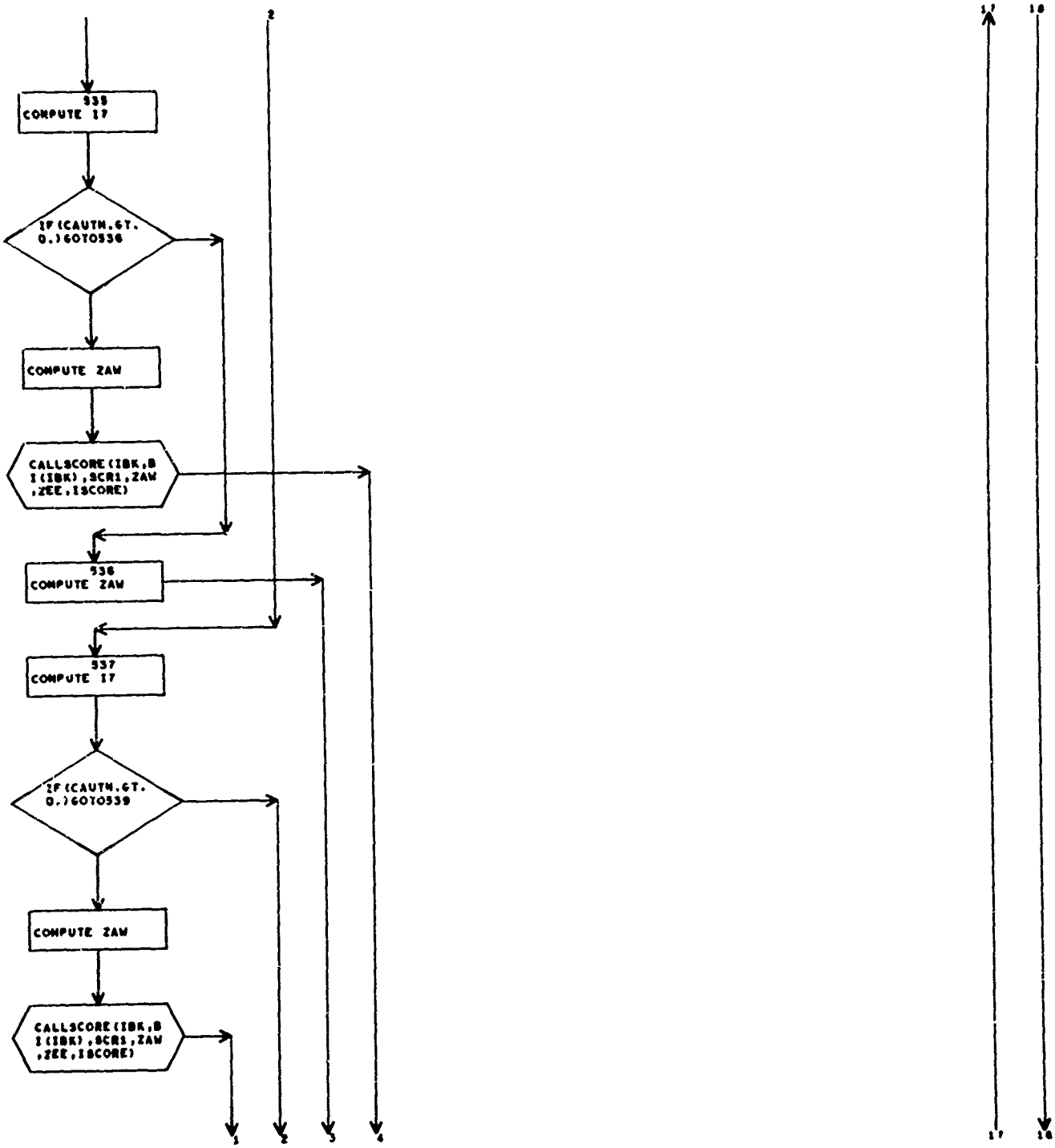

IF(IT-IKO)47
3,473,493
COMPUTE DTH,K,M
CALLCOEF(UB,DTH
,K,N,BI)
502
COMPUTE KSET,I7
,ZEE,ZAW,KSET2,
IDX,MI,IBK
DO515IB=IDX,MI,
2
COMPUTE BIBI(IB
),MI1
515
CONTINUE
520
COMPUTE BIMAX,I
BKD
DO529JIPS=1,MI

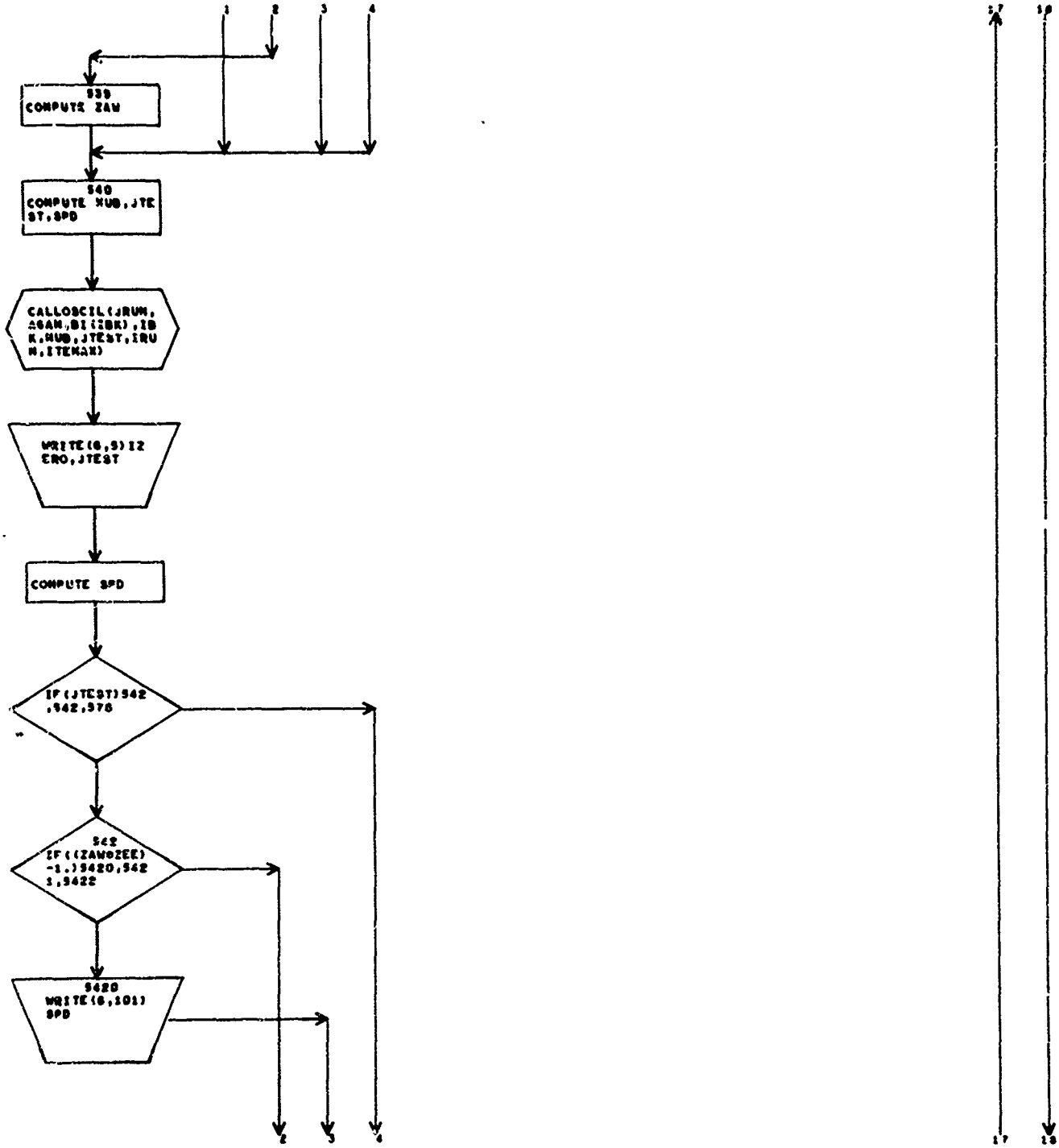

IF(IT-IKO)47
3,473,498
COMPUTE DTH,K,N
CALLCOEF(UB,DTH
,K,N,BI)
502
COMPUTE KSET,I7
,ZEE,ZAW,KSET2,
IDX,NI,IBK
DO515IB=IDX,NI,
2
COMPUTE BIBI(IB
),NI1
515
CONTINUE
520
COMPUTE BIMAX,I
BKD
DO525JIPS=1,NI

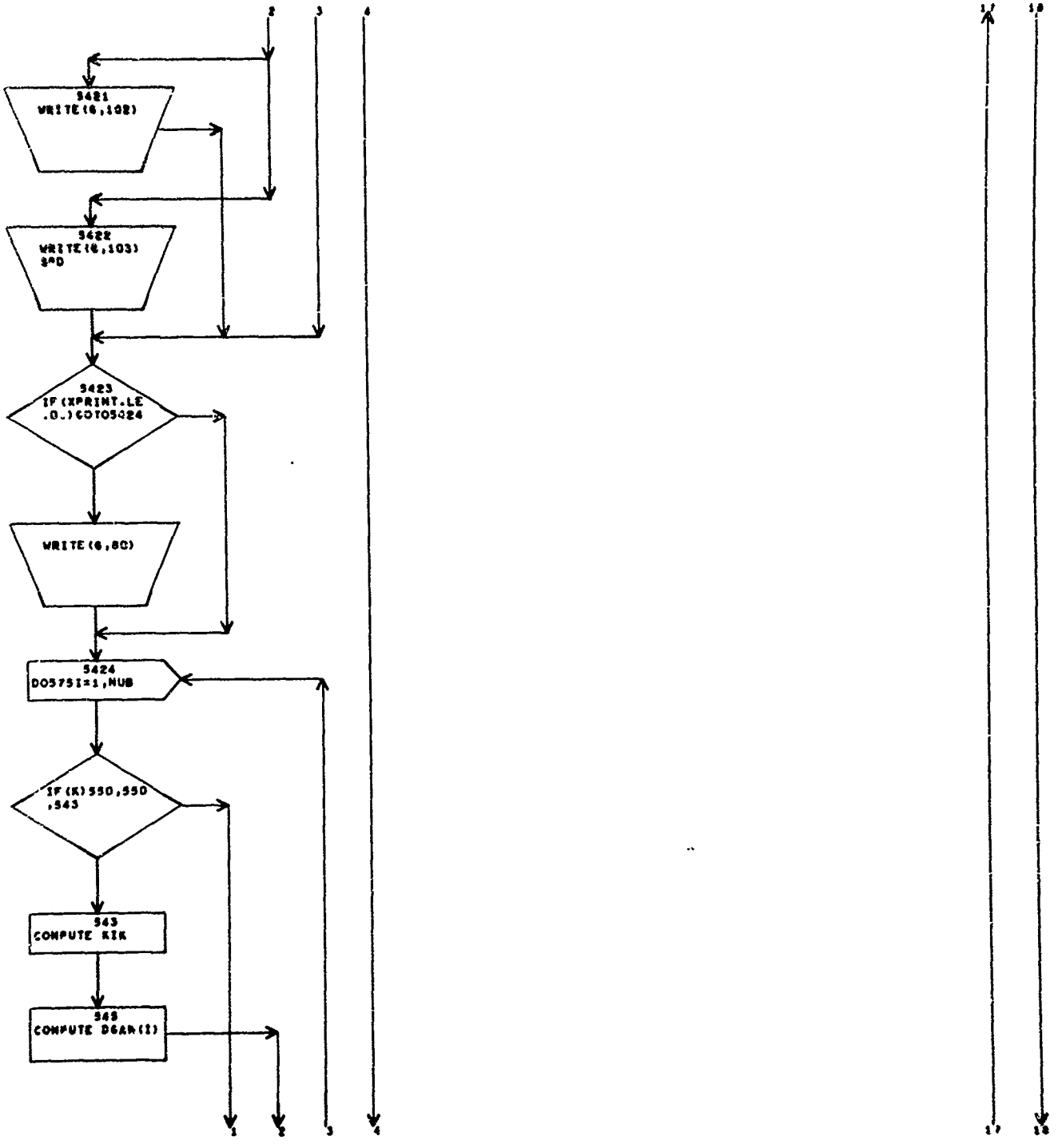


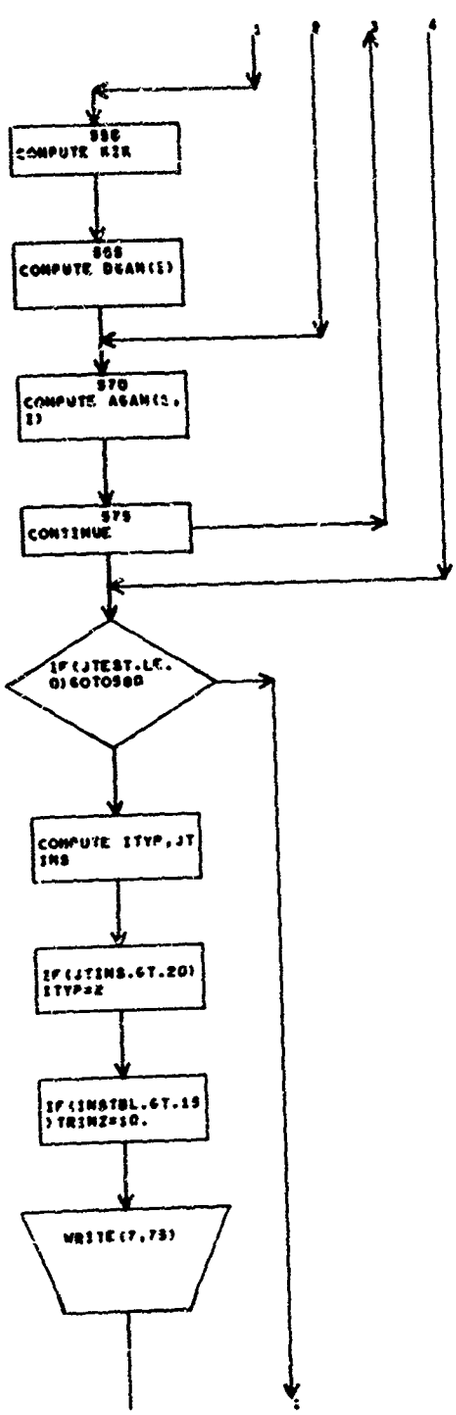

2
COMPUTE IPS
IF(BINAX-BIB
I(IPS))925,9
25,929
925
COMPUTE BINAX,I
BKD
929
CONTINUE
WRITE(6,9)IZ
ERO,IBK
IF(BINAX-0.8
*DUAVE)930,
930,927
COMPUTE CAUTN
933
IF(K)935,935
,937
2

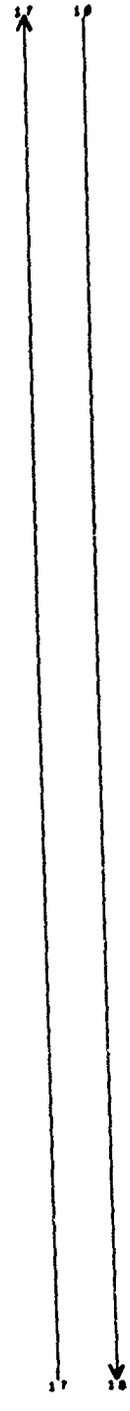

17
18
17
18

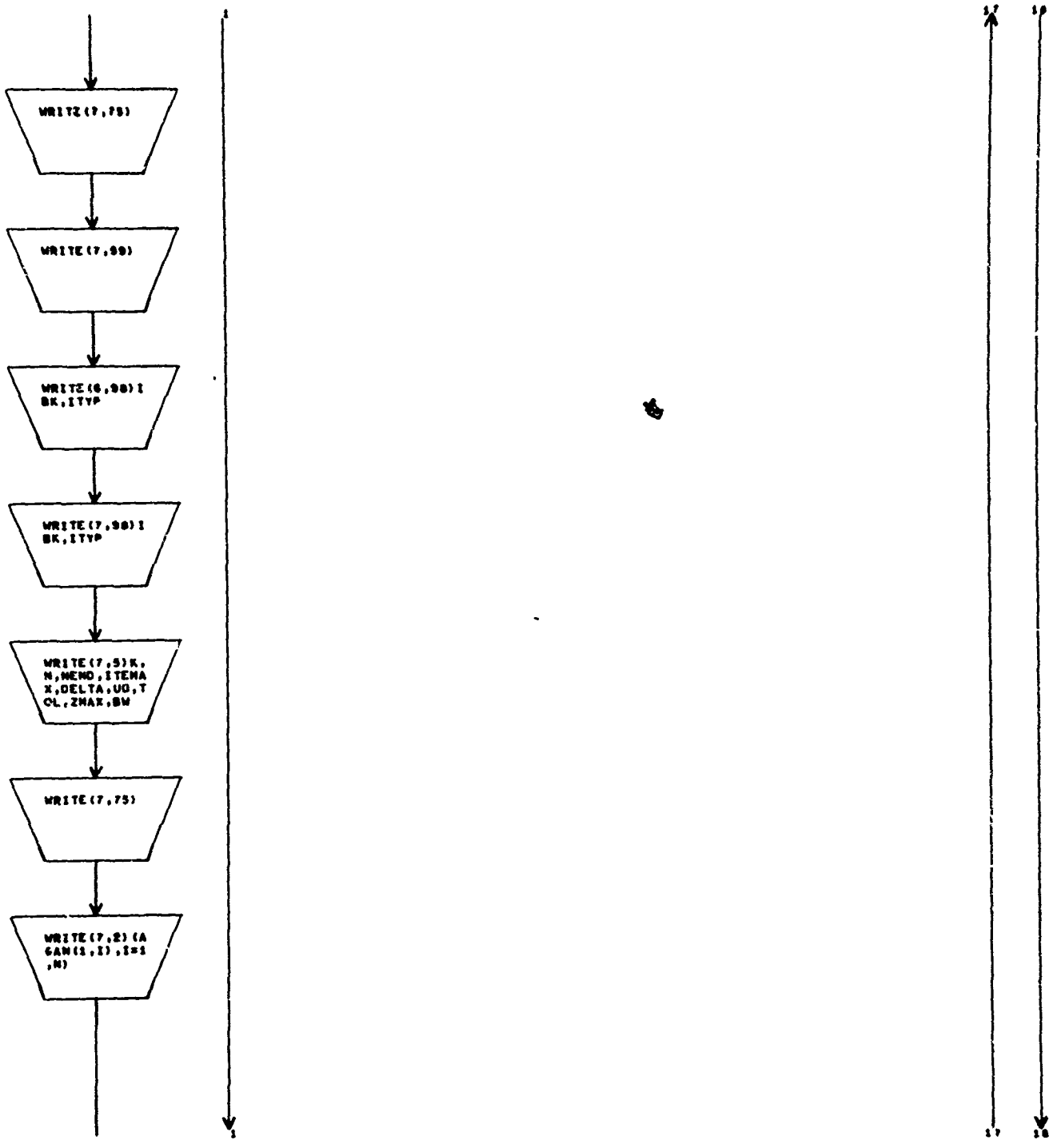

935
COMPUTE IT
IF(CAUTN.GT.
0.)GOTO936
COMPUTE ZAW
CALLSCORE(IBK,B
I(IBK),SCR1,ZAW
,ZEE,ISCORE)
936
COMPUTE ZAW
937
COMPUTE IT
IF(CAUTN.GT.
0.)GOTO939
COMPUTE ZAW
CALLSCORE(IBK,B
I(IBK),SCR1,ZAW
,ZEE,ISCORE)
2
1
2
3
4
17
18

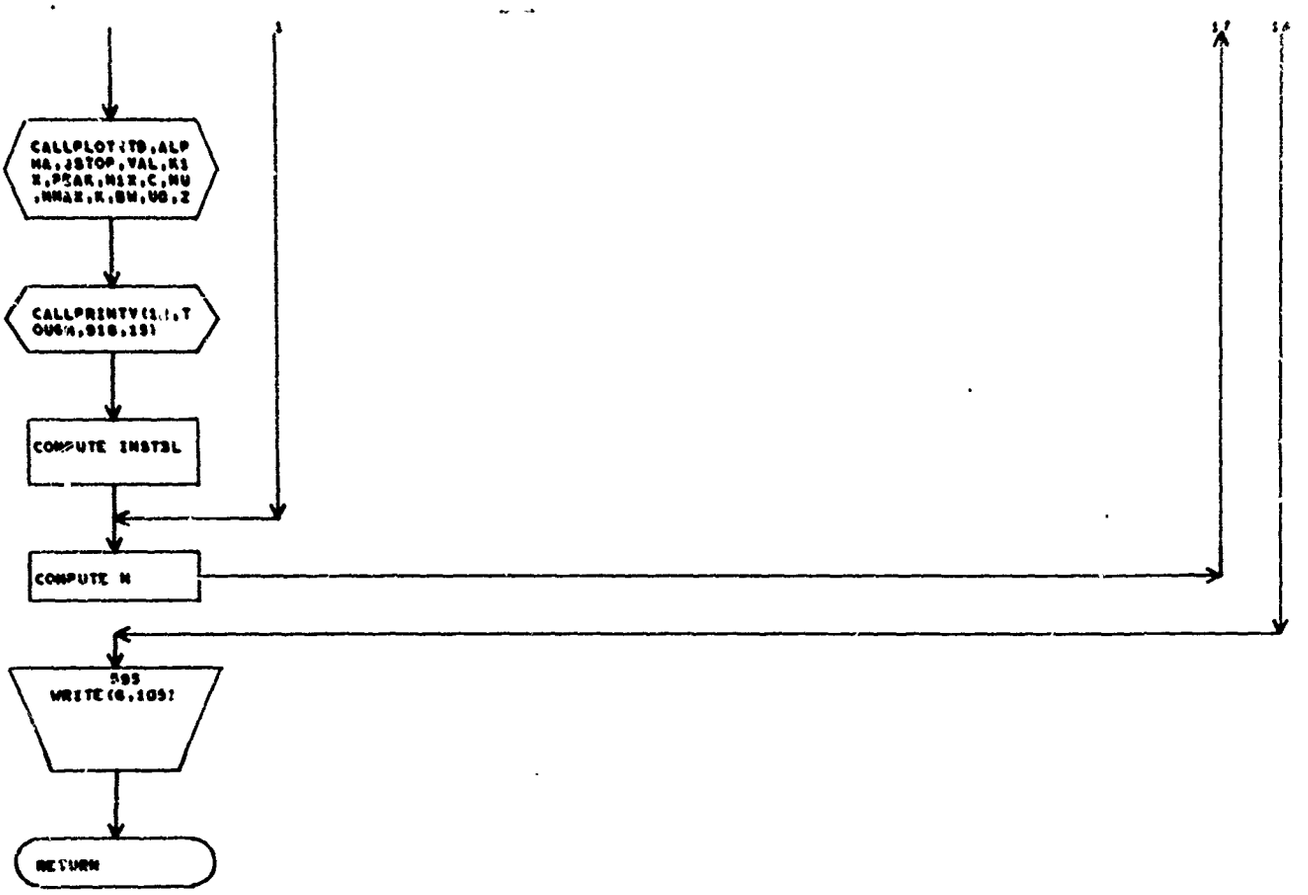

1
2
3
4
939
COMPUTE ZAW
940
COMPUTE XUB,JTEST,SPD
CALLOSCIL(JRUN,AGAN,BI(IBK),IBK,XUB,JTEST,IRUN,ITEMAX)
WRITE(6,9)IERO,JTEST
COMPUTE SPD
IF(JTEST)942,942,976
942
IF((ZAW0ZEE)-1.)9420,9421,9422
9420
WRITE(6,101)SPD
17
18
2
3
4
17
18

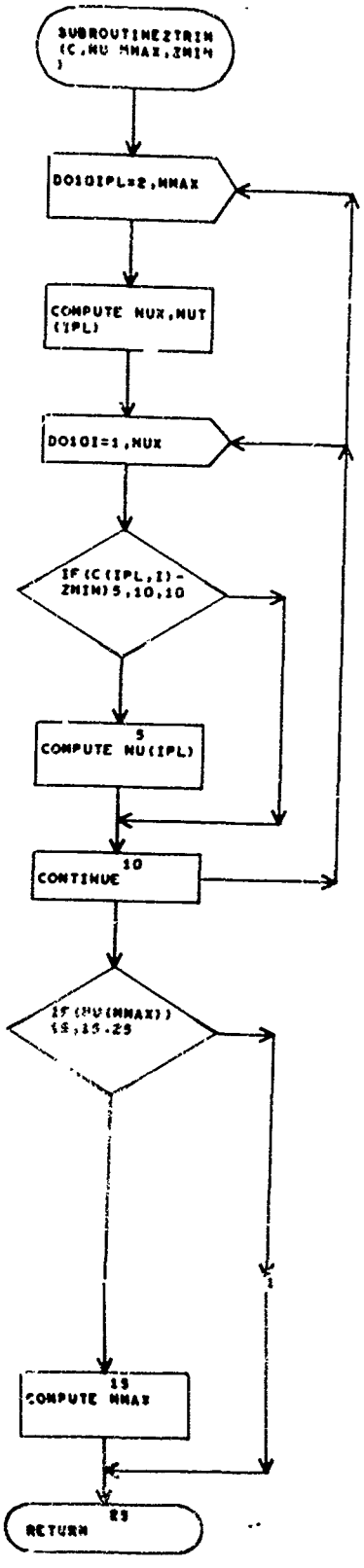

2
3
4
9421
WRITE(6,102)
9422
WRITE(6,103)
END
9423
IF(XPRINT.LE
.0.)GOTO5424
WRITE(6,80)
5424
DO5751=1,NUB
IF(K)550,550
,543
543
COMPUTE RIK
545
COMPUTE DGAR(I)
1
2
3
4
17
18

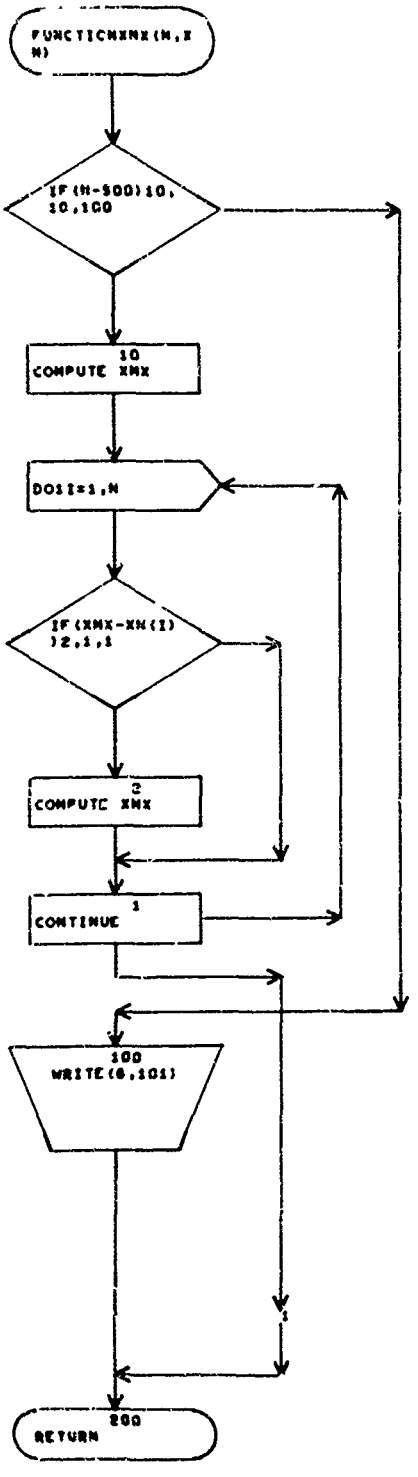

SSE
COMPUTE KIR
SGS
COMPUTE BGAN(I)
S70
COMPUTE AGAN(I,
J)
S75
CONTINUE
IF(JTEST.LE.
0)GOTO580
COMPUTE ITYP,JT
INS
IF(JTINS.GT.20)
ITYP=2
IF(INSTBL.GT.15
)TRINZ=90.
WRITE(7,75)

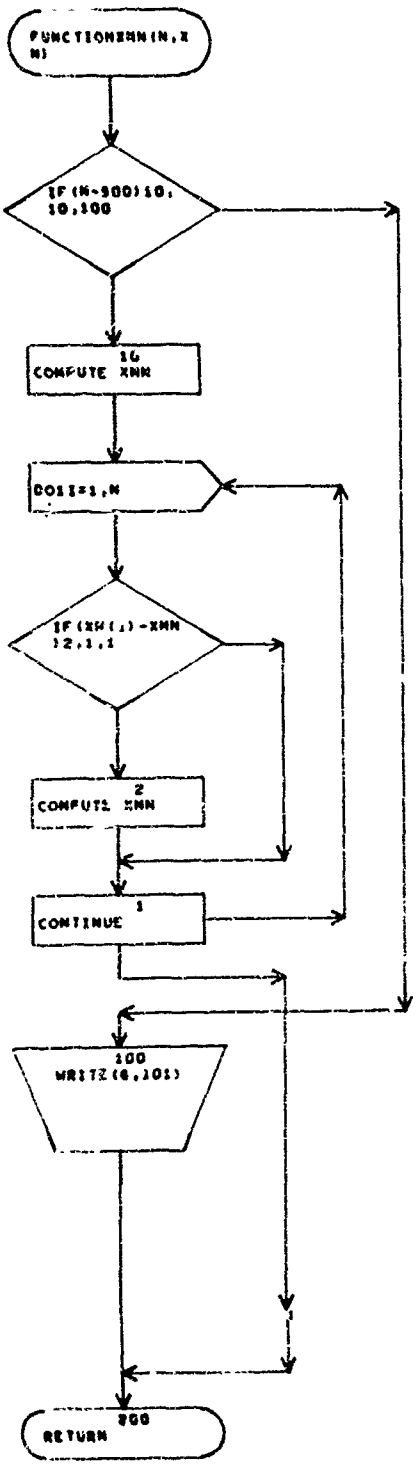


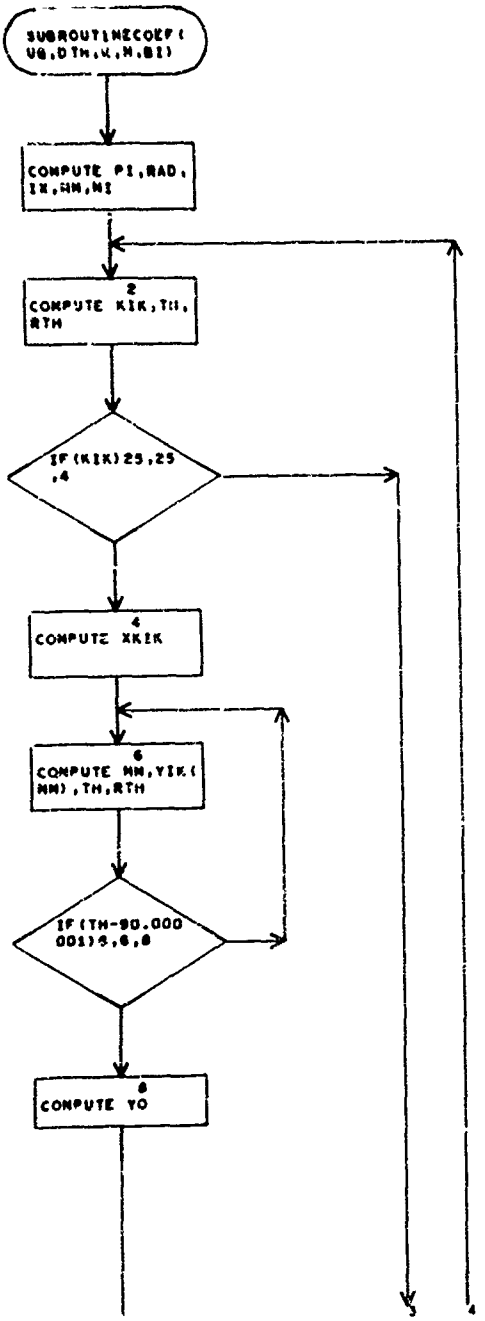

WRITE(7,75)
WRITE(7,99)
WRITE(6,98)I BK,ITYP
WRITE(7,98)I BK,ITYP
WRITE(7,5)K, N,MEND,ITEMA X,DELTA,UO,T OL,ZMAX,BW
WRITE(7,75)
WRITE(7,2)(A GAN(1,I),I=1 ,N)

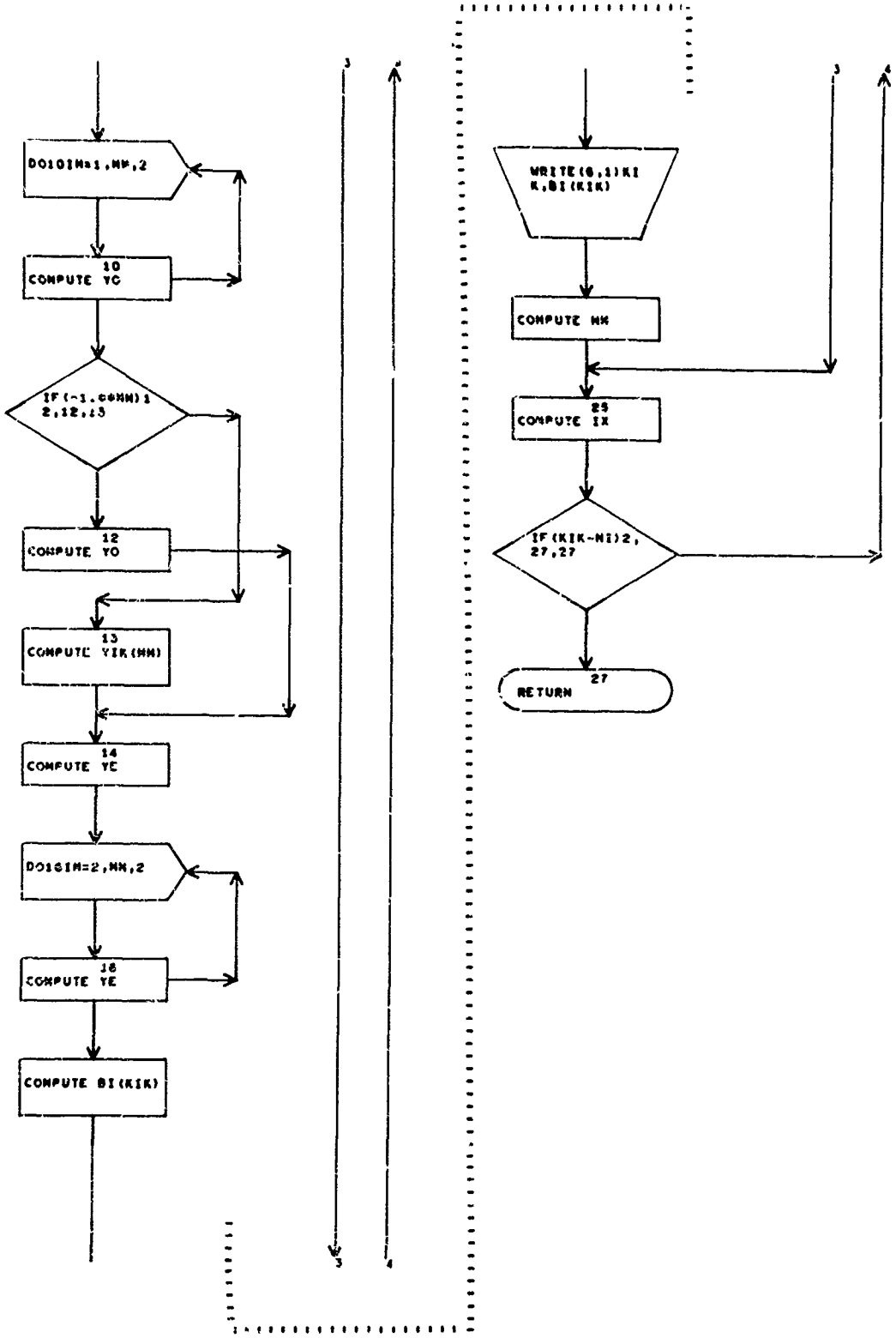

CALLPLOT(T0,ALP
HA,JSTOP,VAL,K1
K,PSAK,N1K,C,NU
,NMAX,K,BM,VG,Z
CALLPRINTV(1,1,T
OUG%,910,191
COMPUTE INST3L
COMPUTE N
595
WRITE(6,109)
RETURN

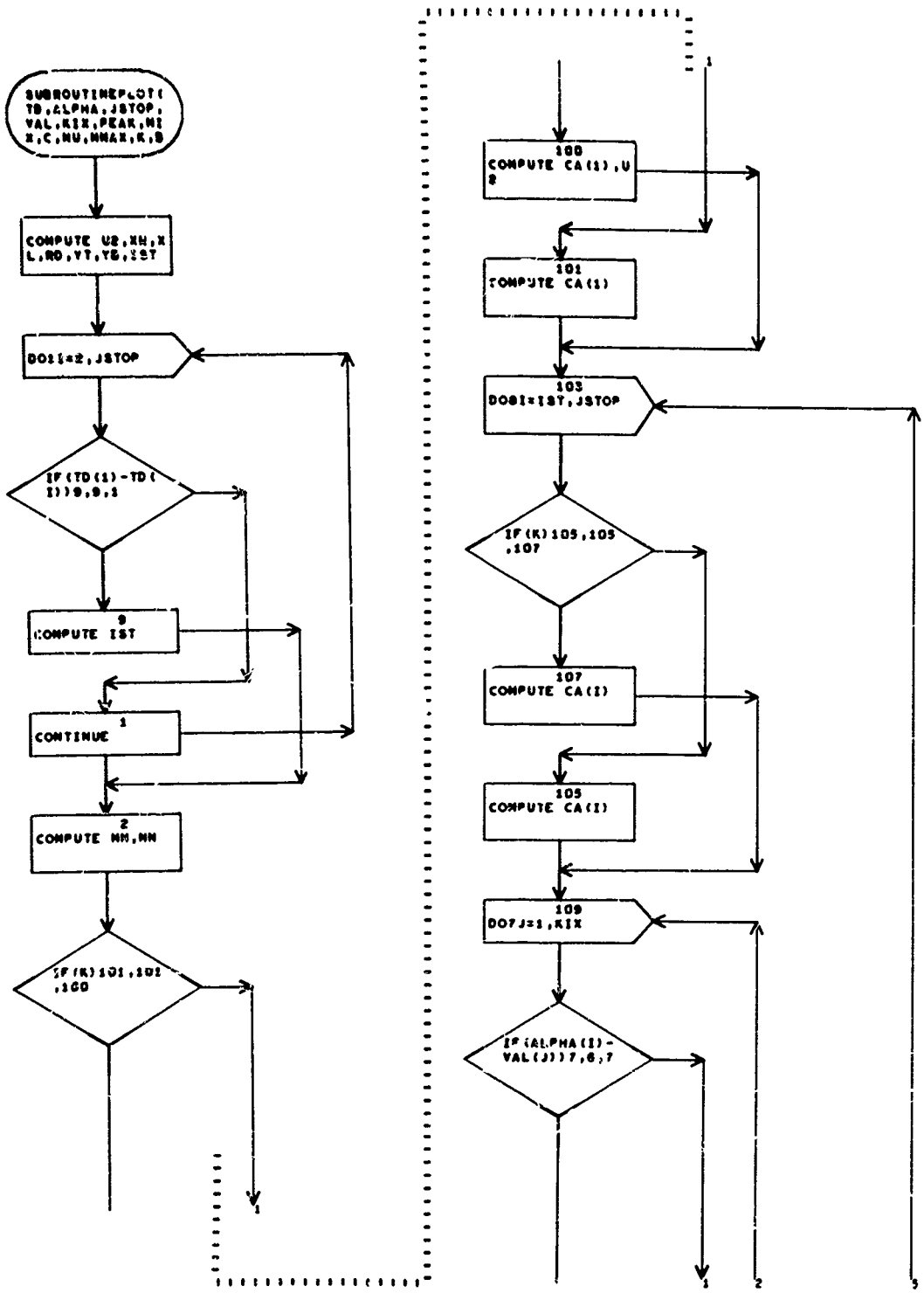

SUBROUTINEZTRIM (C,NU MMAX,ZMIN)
DO10IPL=2,MMAX
COMPUTE NUX,NUT (IPL)
DO10I=1,NUX
IF(C(IPL,I)-ZMIN)5,10,10
5 COMPUTE NU(IPL)
10 CONTINUE
IF(NU(MMAX))15,15,25
15 COMPUTE MMAX
25 RETURN

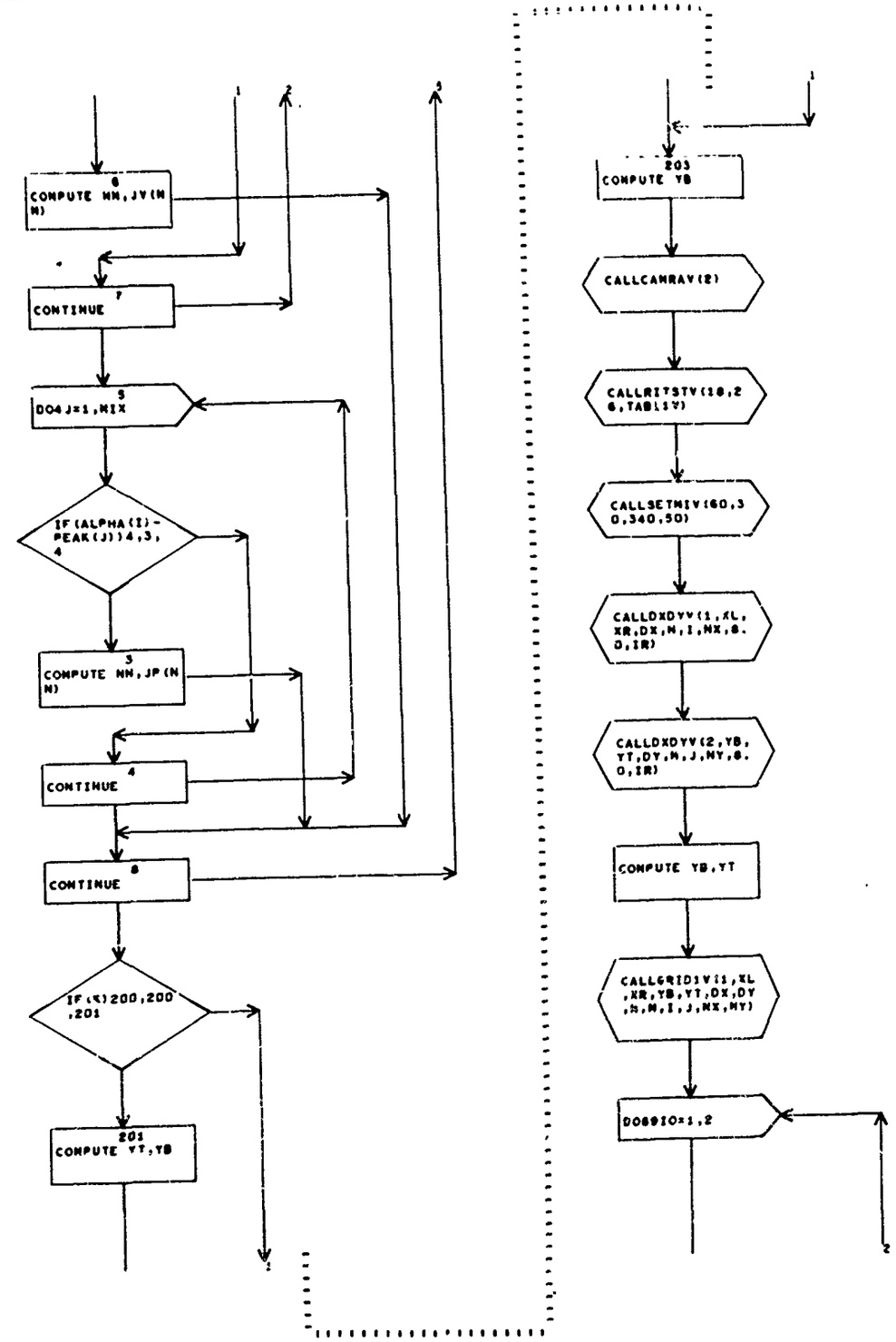

FUNCTICNXMX(N,X M)
IF(N-500)10, 10,100
10 COMPUTE XMX
DO1I=1,N
IF(XMX-XN(I))2,1,1
2 COMPUTE XMX
1 CONTINUE
100 WRITE(6,101)
200 RETURN

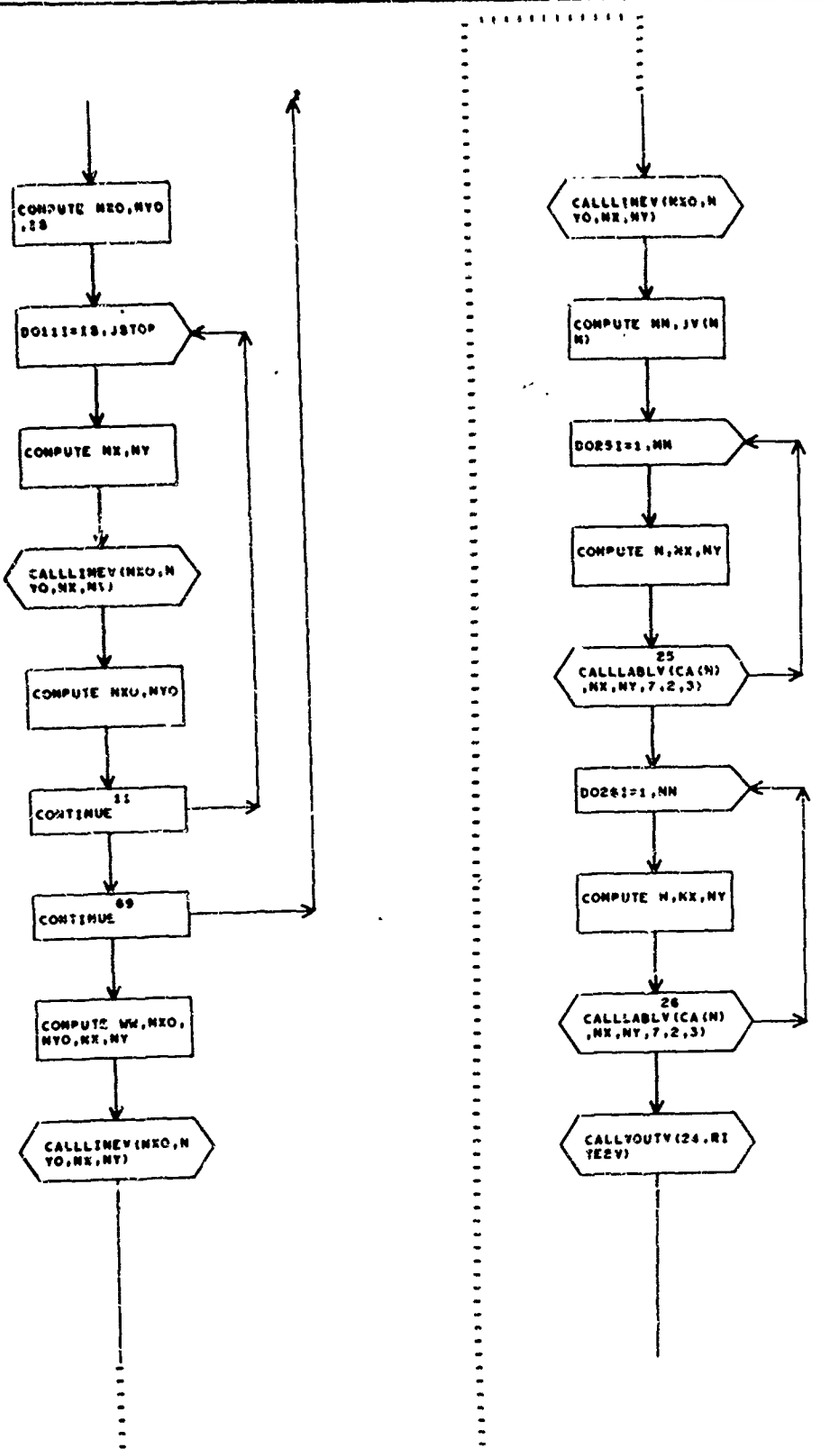

FUNCTIONZHN(N,X
M)
IF(N-900)10,
10,100
16
COMPUTE XNN
DO11I=1,N
IF(XM(I)-XNN
)2,1,1
2
COMPUTE XNN
1
CONTINUE
100
WRITE(6,101)
200
RETURN

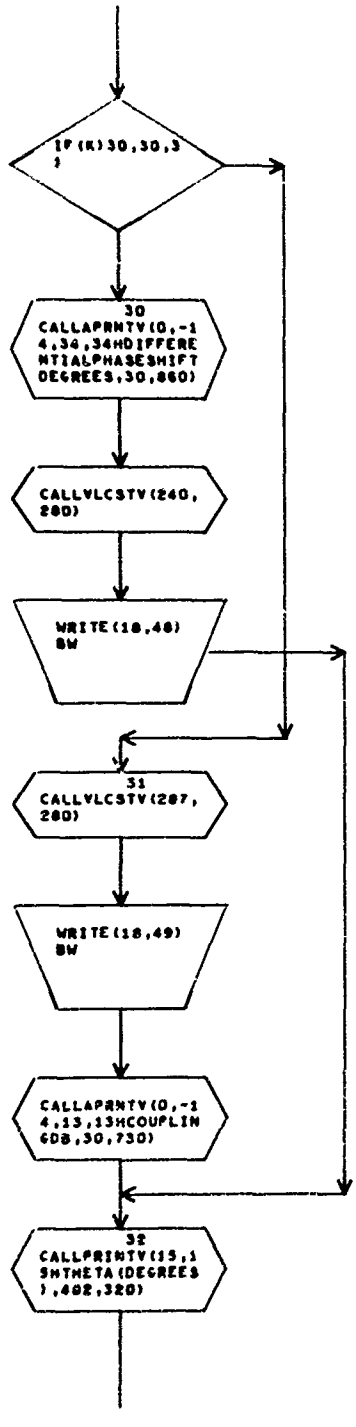

SUBROUTINECOEF(
UG,DTH,W,N,BI)
COMPUTE PI,RAD,
IX,HN,NI
2
COMPUTE KIK,TH,
RTH
IF(KIK)25,25
,4
4
COMPUTE XKIK
6
COMPUTE HN,YIK(
NN),TH,RTH
IF(TH-90.000
001)6,6,8
8
COMPUTE YO

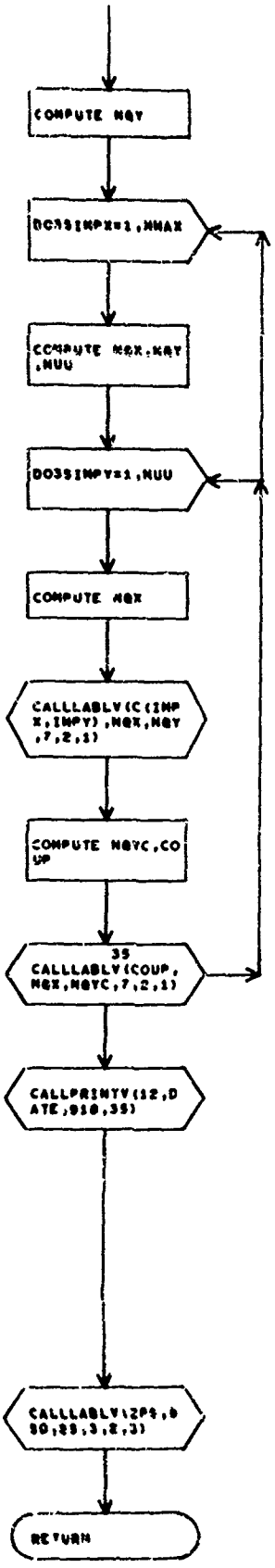

DO10IM=1,MM,2
10
COMPUTE YC
IF(-1.0+MM)1
2,12,13
12
COMPUTE YO
13
COMPUTE YIR(MM)
14
COMPUTE YE
DO15IM=2,MM,2
16
COMPUTE YE
COMPUTE BI(KIK)
3
4
WRITE(6,1)KI
K,BI(KIK)
COMPUTE MM
25
COMPUTE IX
IF(KIK-NI)2,
27,27
27
RETURN

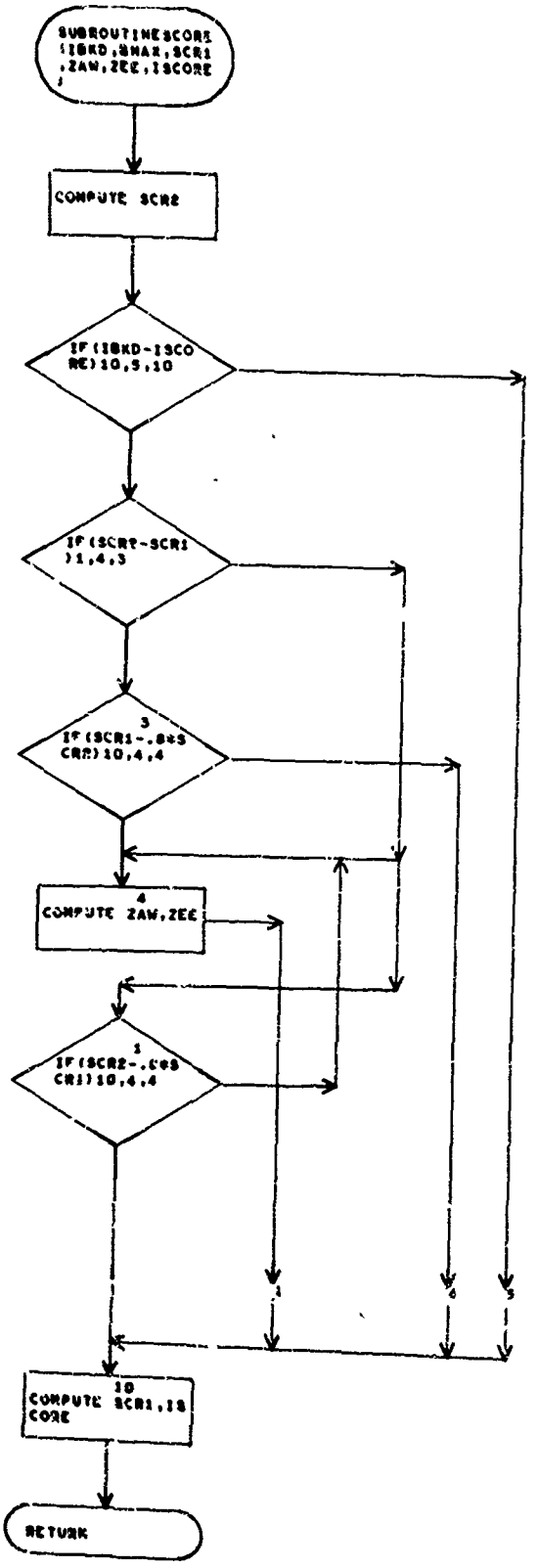

SUBROUTINEPLOT(TD,ALPHA,JSTOP,VAL,KIX,PEAK,NIX,C,NU,NMAX,K,B
COMPUTE U2,XN,XL,RO,YT,YB,IST
DO1I=2,JSTOP
IF(TD(1)-TD(I))9,9,1
9 COMPUTE IST
1 CONTINUE
2 COMPUTE NM,NN
IF(K)101,101,100
100 COMPUTE CA(1),U2
101 COMPUTE CA(1)
103 DO8I=IST,JSTOP
IF(K)105,105,107
107 COMPUTE CA(I)
105 COMPUTE CA(I)
109 DO7J=1,KIX
IF(ALPHA(I)-VAL(J))7,6,7

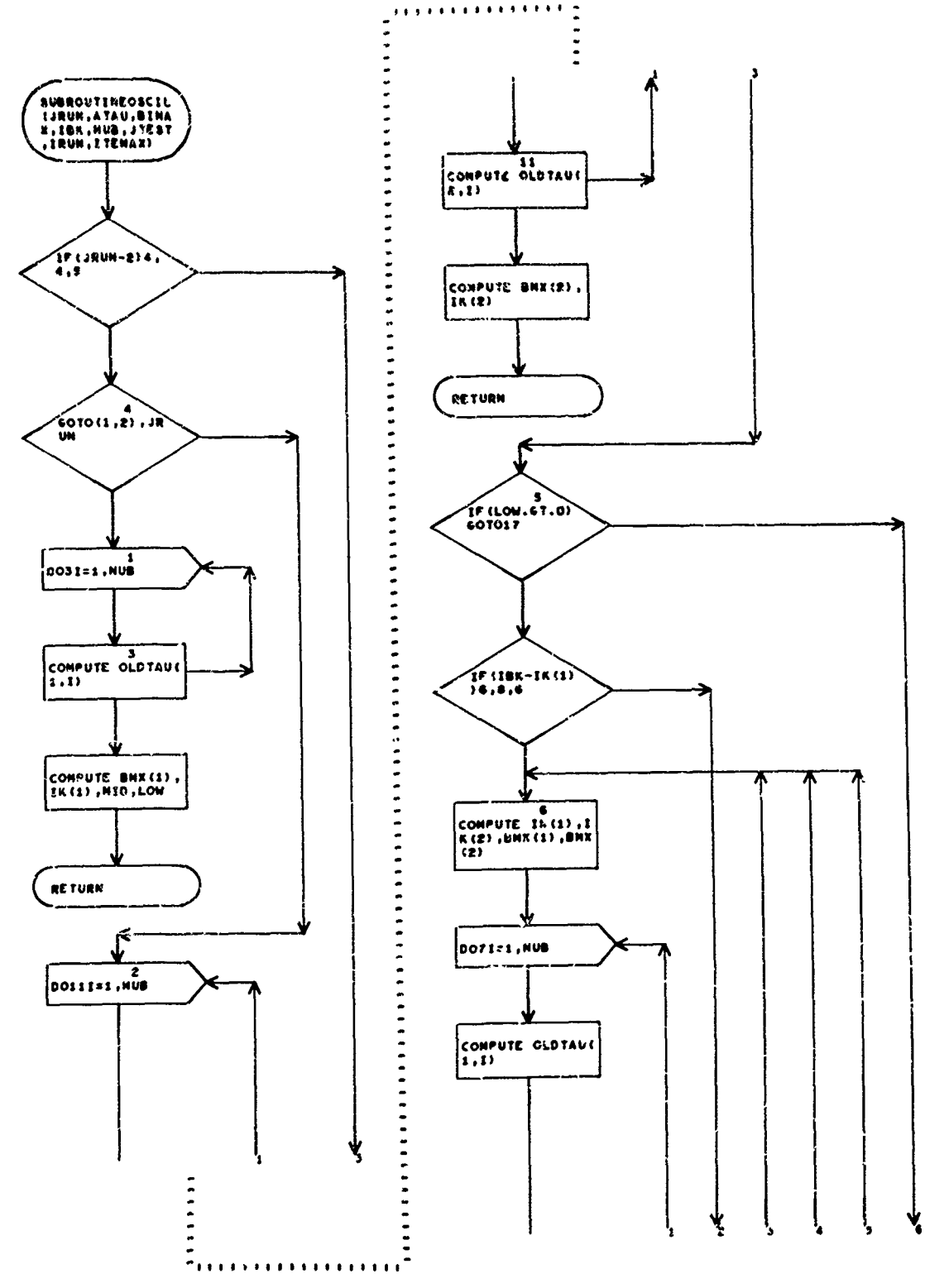

6
COMPUTE NN, JV(N N)
7
CONTINUE
5
DO4 J=1, MIX
IF (ALPHA(I) - PEAK(J))4, 3, 4
3
COMPUTE NN, JP(N N)
4
CONTINUE
8
CONTINUE
IF (K)200, 200, 201
201
COMPUTE YT, YB
203
COMPUTE YB
CALLCAMRAV(2)
CALLRITSTV(18, 26, TABLIV)
CALLSETMIV(60, 30, 340, 50)
CALLDXDYV(1, XL, XR, DX, N, I, NX, 8.0, IR)
CALLDXDYV(2, YB, YT, DY, N, J, NY, 8.0, IR)
COMPUTE YB, YT
CALLGRIDIV(1, XL, XR, YB, YT, DX, DY, N, M, I, J, NX, MY)
DO6910=1, 2

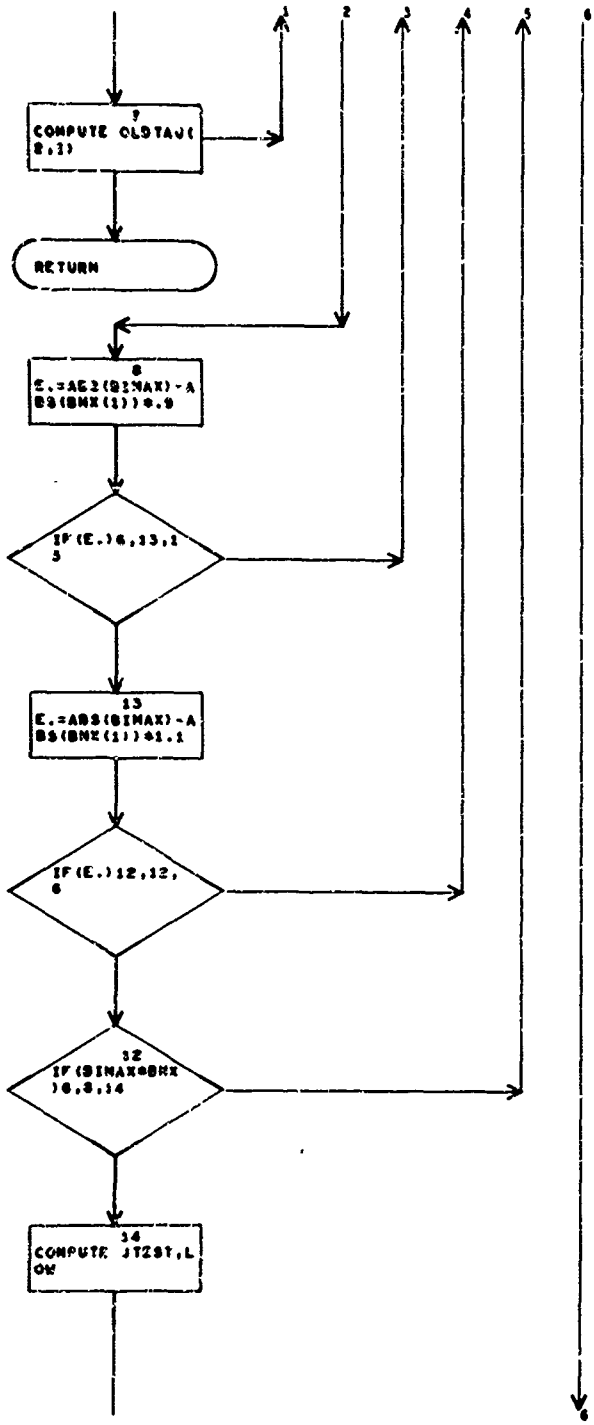

COMPUTE NXO,NYO ,IS
DO111=IS,JSTOP
COMPUTE NX,NY
CALLLINEV(NXO,N YO,NX,NY)
COMPUTE NXO,NYO
11 CONTINUE
69 CONTINUE
COMPUTE MM,NXO, NYO,NX,NY
CALLLINEV(NXO,N YO,NX,NY)
CALLLINEV(NXO,N YO,NX,NY)
COMPUTE NN,JV(N N)
DO25I=1,NN
COMPUTE N,XX,NY
25 CALLLABLV(CA(N) ,NX,NY,7,2,3)
DO26I=1,NN
COMPUTE N,XX,NY
26 CALLLABLV(CA(N) ,NX,NY,7,2,3)
CALLYOUTV(24,RI TEZV)

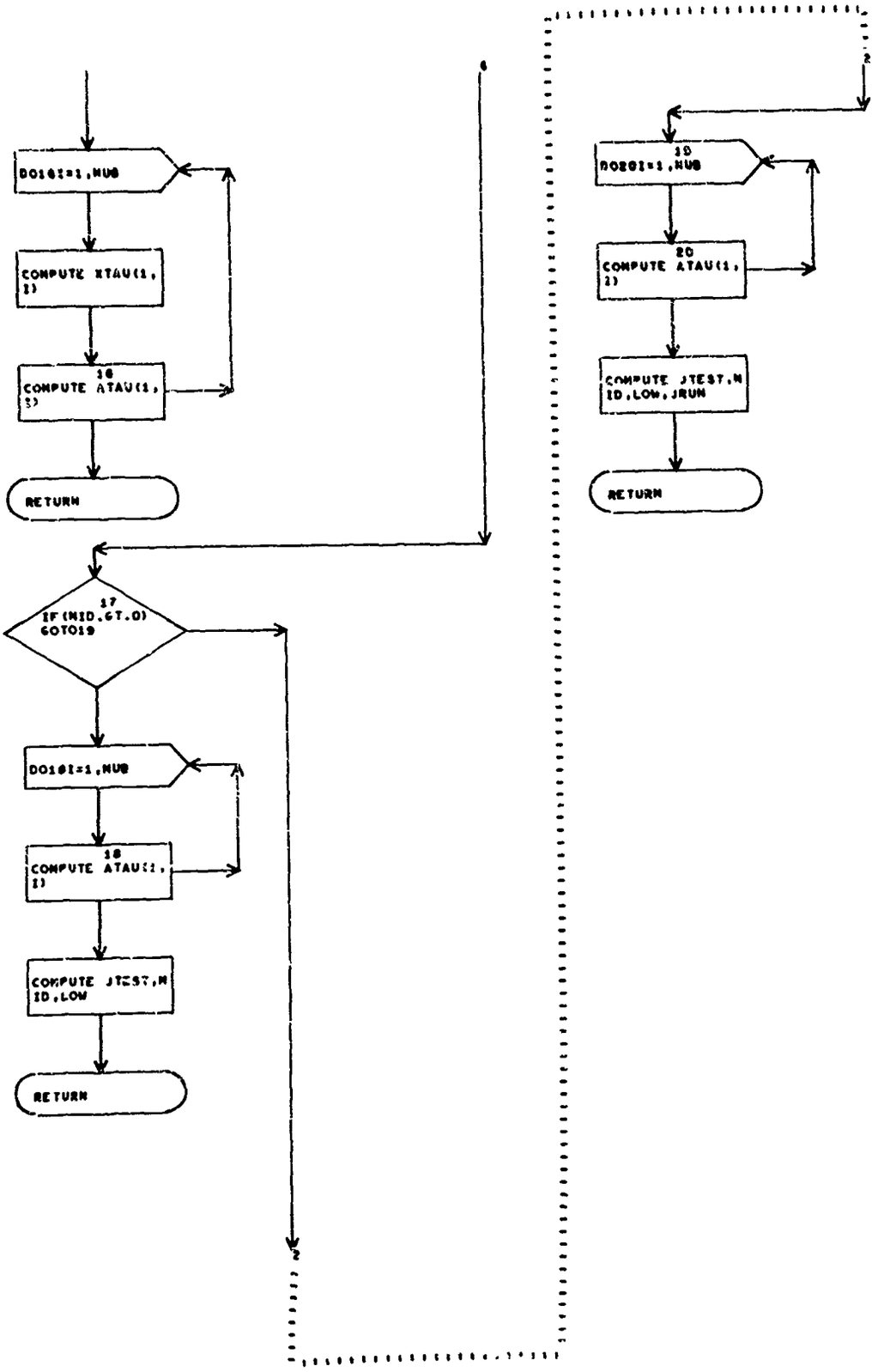

IF(K)30,30,3
1
30
CALLAPRNTV(0,-1
4,34,34HDIFFERE
NTIALPHASESHIFT
DEGREES,30,860)
CALLVLCSTV(240,
280)
WRITE(18,48)
BW
31
CALLVLCSTV(287,
280)
WRITE(18,49)
BW
CALLAPRNTV(0,-1
4,13,13HCOUPLIN
608,30,730)
32
CALLPRINTV(15,1
5HTHETA(DEGREES
),492,320)

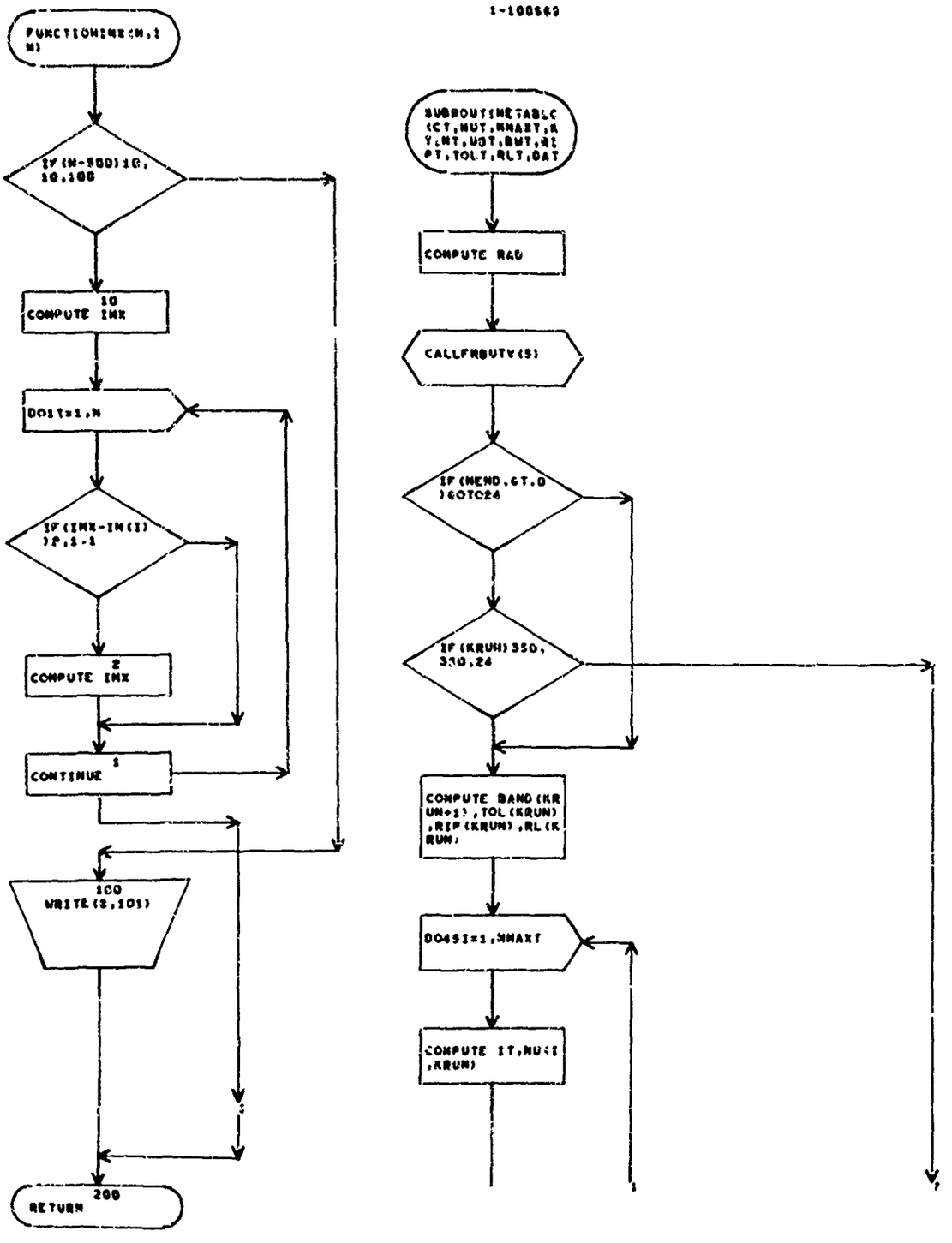

COMPUTE NBY
DO 35 IMPX=1,NMAX
COMPUTE NBX,NBY,NUU
DO 35 IMPY=1,NUU
COMPUTE NBX
CALL LABLV(C(IMPX,IMPY),NBX,NBY,7,2,1)
COMPUTE NBYC,COUP
35 CALL LABLV(COUP,NBX,NBYC,7,2,1)
CALL PRINTV(12,DATE,910,35)
CALL LABLV(ZPS,850,25,3,2,3)
RETURN

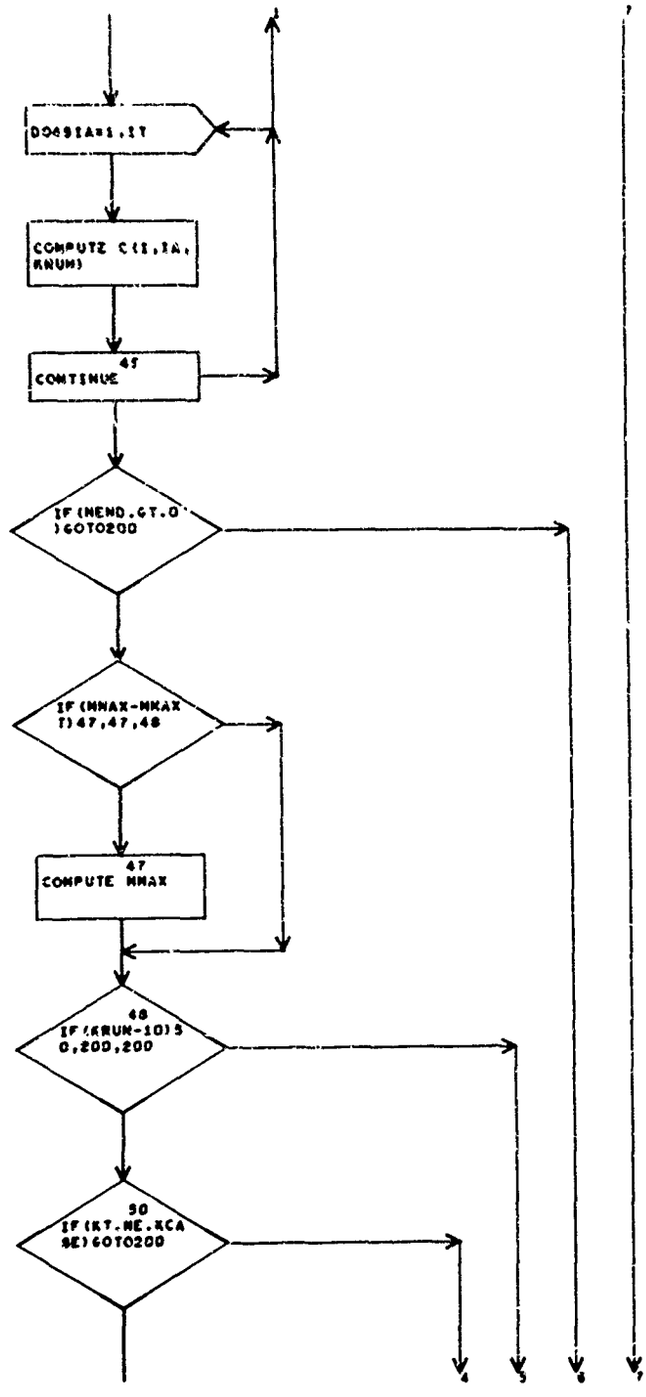

SUBROUTINE SCORE(IBKD,BMAX,SCR1,ZAW,ZEE,ISCORE)
COMPUTE SCR2
IF(IBKD-ISCORE)10,5,10
IF(SCR2-SCR1)1,4,3
3 IF(SCR1-.8*SCR2)10,4,4
4 COMPUTE ZAW,ZEE
1 IF(SCR2-.6*SCR1)10,4,4
10 COMPUTE SCR1,ISCORE
RETURN

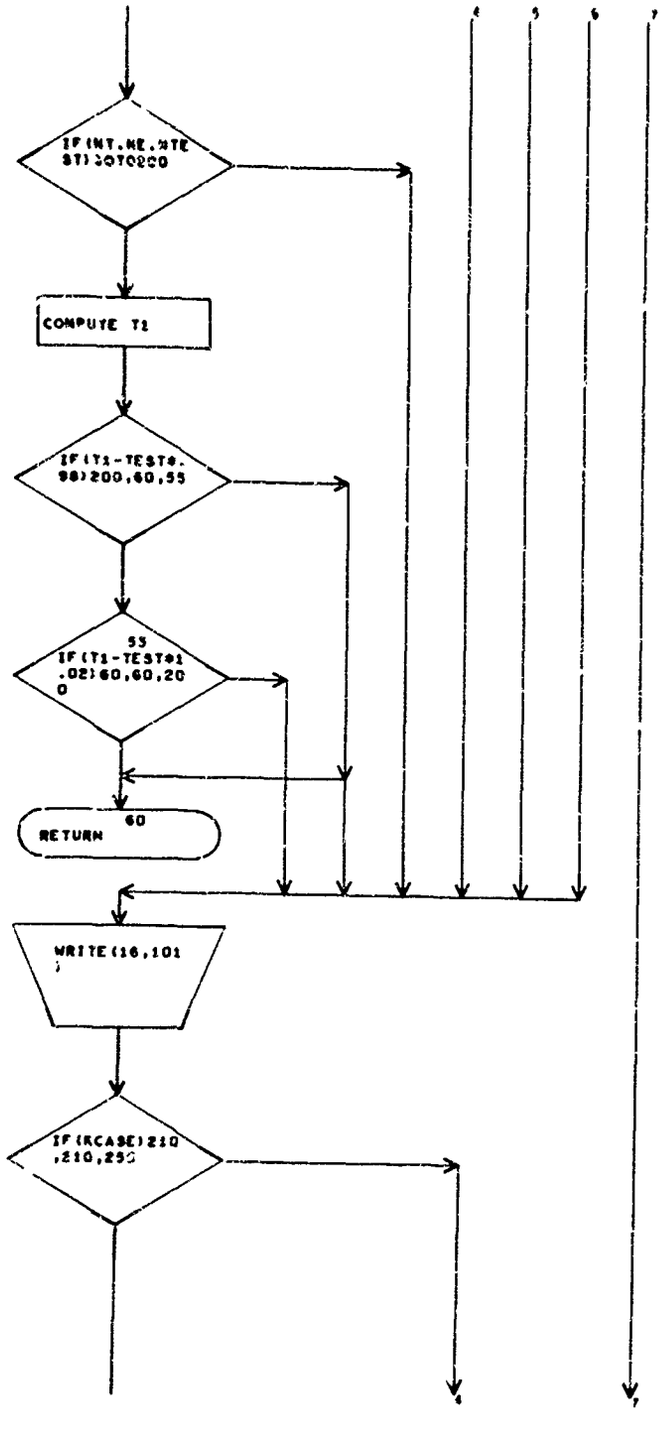

SUBROUTINEOSCIL
(JRUN,ATAU,BINA
X,IBK,NUB,JTEST
,IRUN,ITEMAX)
IF(JRUN-2)4,
4,9
4
GOTO(1,2),JR
UN
1
DO3I=1,NUB
3
COMPUTE OLDTAU(
1,I)
COMPUTE BMX(1),
IK(1),MID,LOW
RETURN
2
DO11I=1,NUB
11
COMPUTE OLDTAU(
2,I)
COMPUTE BMX(2),
IK(2)
RETURN
5
IF(LOW.GT.0)
GOTO17
IF(IBK-IK(1)
)6,8,6
6
COMPUTE IK(1),I
K(2),BMX(1),BMX
(2)
DO7I=1,NUB
COMPUTE OLDTAU(
1,I)

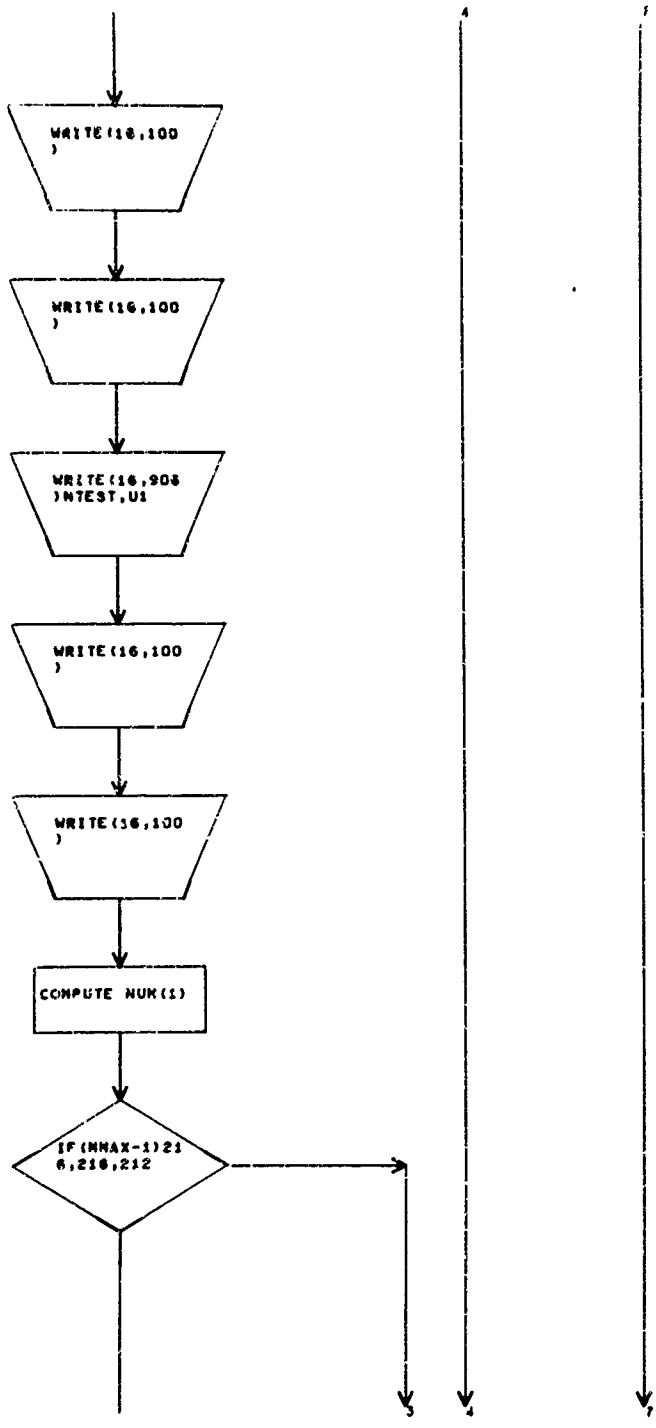

1
2
3
4
5
6
9
COMPUTE OLDTAU(
2,1)
RETURN
8
E.=ABS(BINAX)-A
BS(BNX(1))*.9
IF(E.)6,13,1
3
13
E.=ABS(BINAX)-A
BS(BNX(1))*1.1
IF(E.)12,12,
6
12
IF(BINAX*BNX
)6,3,14
14
COMPUTE JTZST,L
OW
6

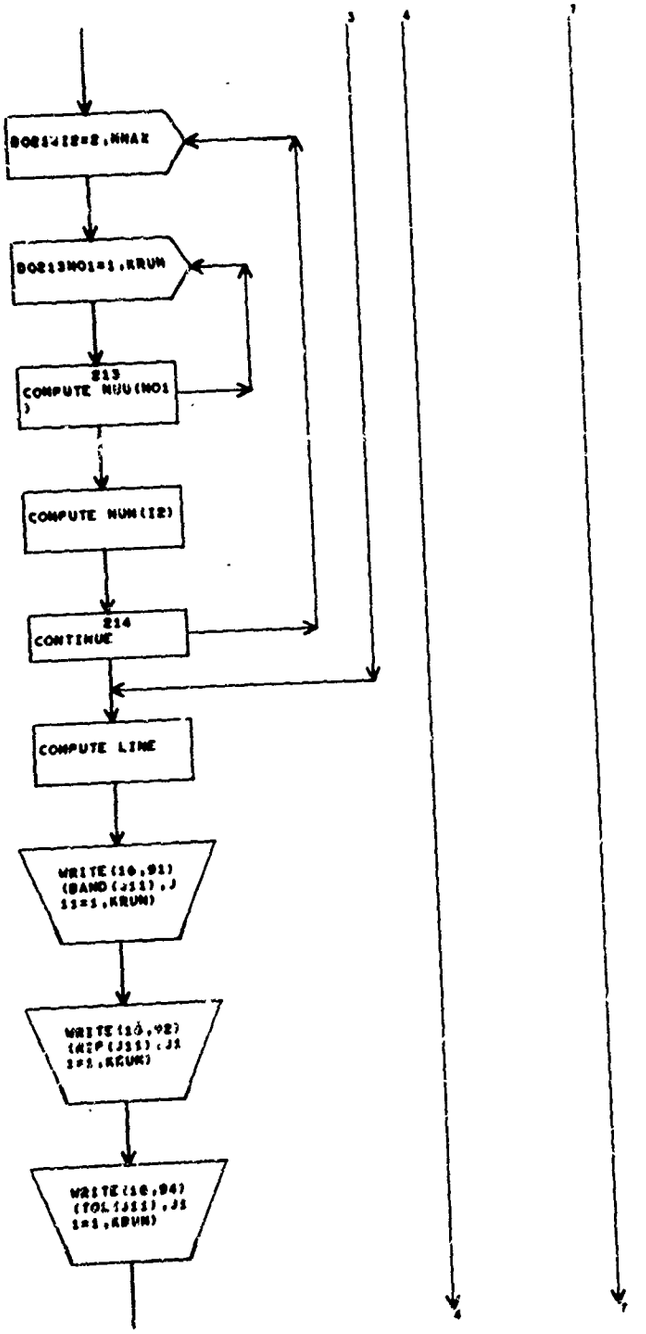

DO16I=1,NUB
COMPUTE XTAU(1,I)
16
COMPUTE ATAU(1,I)
RETURN
17
IF(NID.GT.0)GOTO19
DO18I=1,NUB
18
COMPUTE ATAU(1,I)
COMPUTE JTEST,NID,LOW
RETURN
19
DO20I=1,NUB
20
COMPUTE ATAU(1,I)
COMPUTE JTEST,NID,LOW,JRUN
RETURN

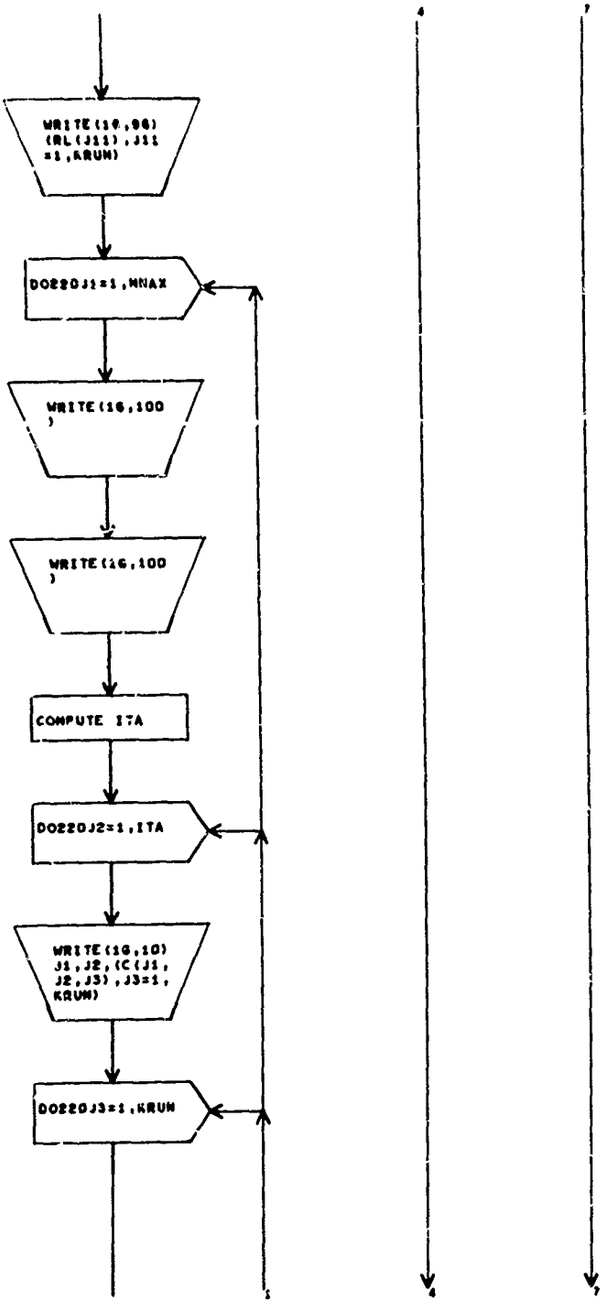

FUNCTION INE(N,I
N)
IF(N-900)10,
10,100
10
COMPUTE INX
DO1I=1,N
IF(INX-IN(I)
)1,1-1
2
COMPUTE INX
1
CONTINUE
100
WRITE(2,101)
200
RETURN
1-100663
SUBROUTINETABLC
(CT,NUT,NMAXT,R
Y,NT,UOT,BWT,NI
PT,TOLT,RLT,DAT
COMPUTE RAD
CALLFRBUTV(5)
IF(NEND.GT.0
)GOTO24
IF(KRUN)350,
350,24
COMPUTE BAND(KR
UN+1),TOL(KRUN)
,RIP(KRUN),RL(K
RUN)
DO451=1,NMAXT
COMPUTE IT,NU(I
,KRUN)

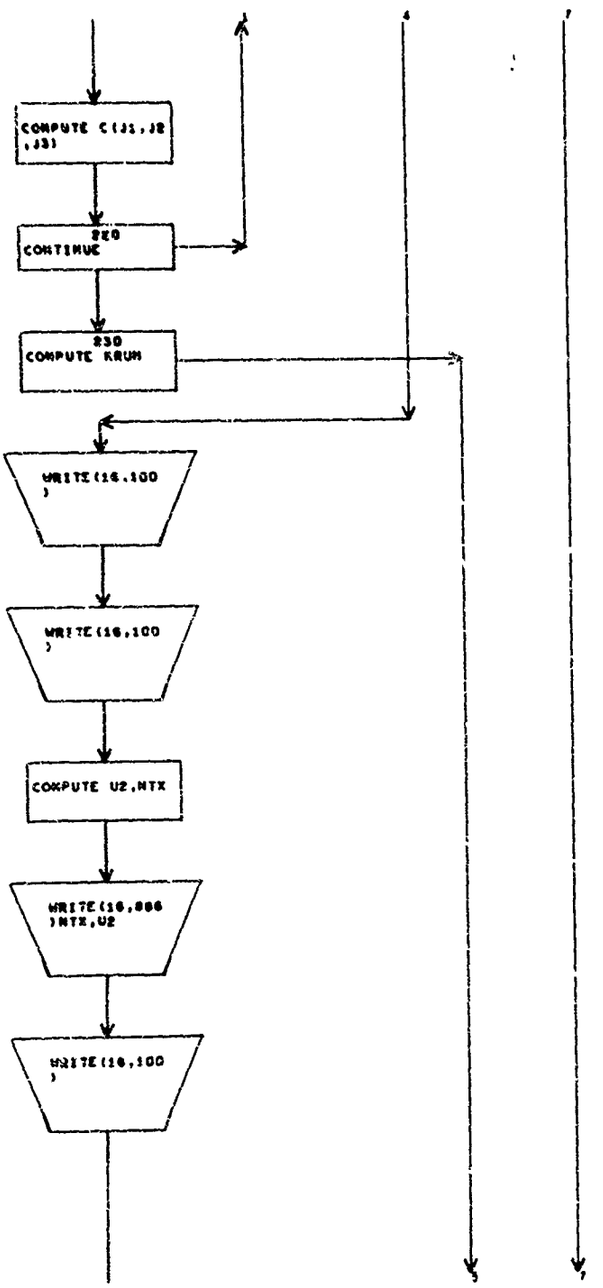

DO 41 IA=1,IT
COMPUTE C(I,IA,KNUM)
41 CONTINUE
IF(NEND.GT.0)GOTO200
IF(NMAX-MMAX)47,47,48
47 COMPUTE MMAX
48 IF(KRUN-10)50,200,200
50 IF(KT.NE.KCASE)GOTO200
4
5
6
7

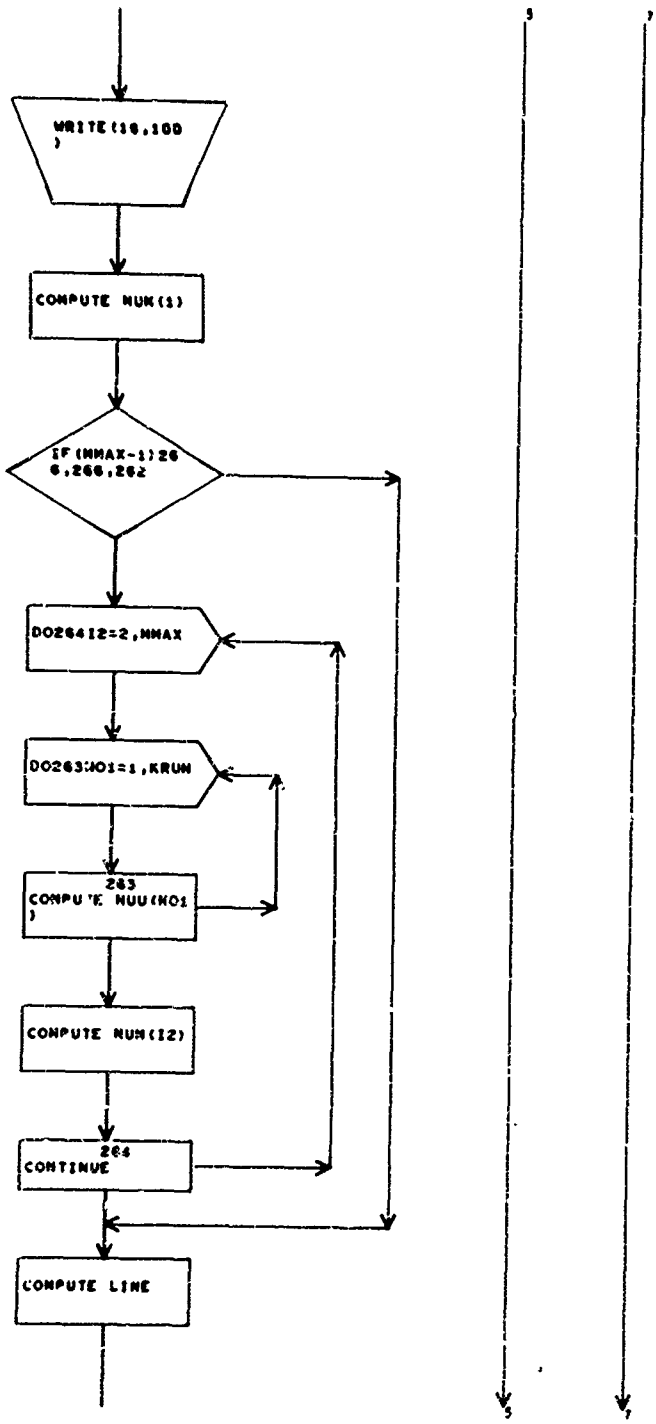

IF(NT.NE.NTE
ST)GOTO200
COMPUTE T1
IF(T1-TEST0.
98)200,60,55
55
IF(T1-TEST01
.02)60,60,20
0
60
RETURN
WRITE(16,101
)
IF(RCASE)210
,210,250

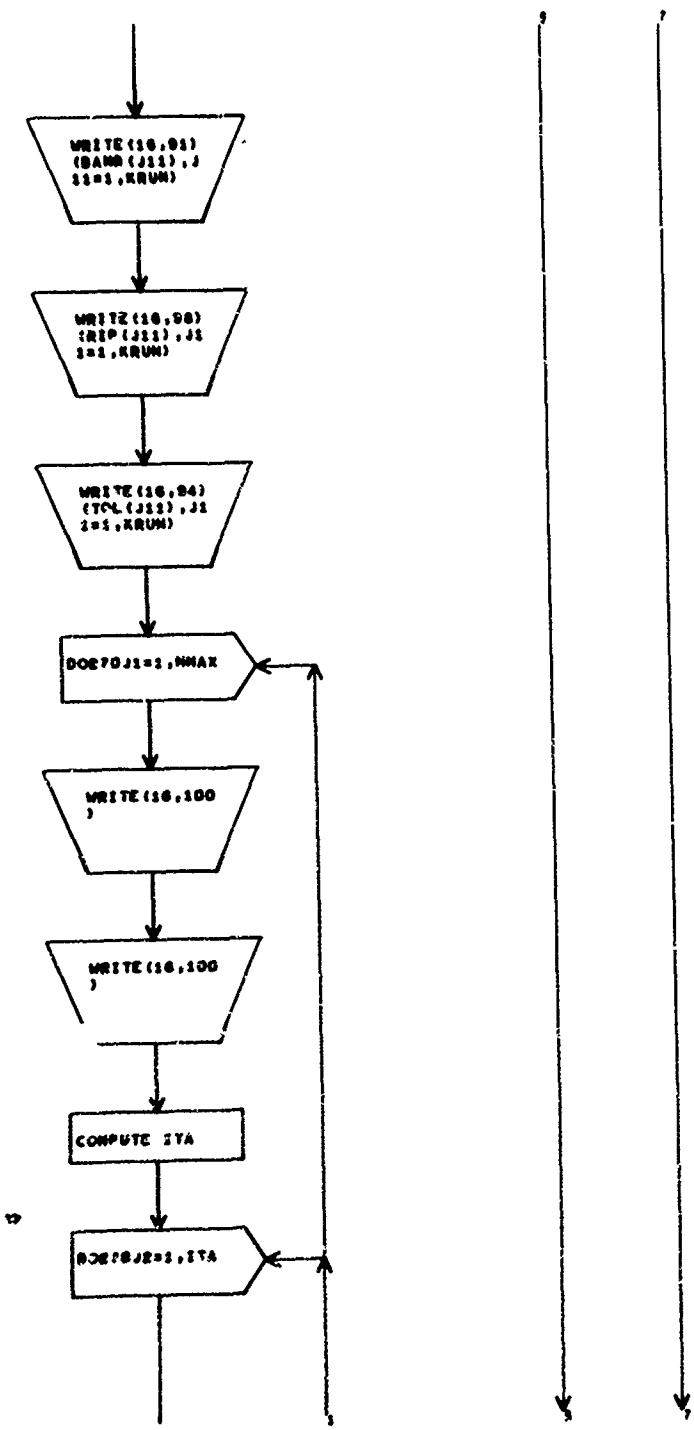

WRITE(16,100
)
WRITE(16,100
)
WRITE(16,905
)NTEST,U1
WRITE(16,100
)
WRITE(16,100
)
COMPUTE NUM(1)
IF(NMAX-1)21
6,216,212
5
4
7

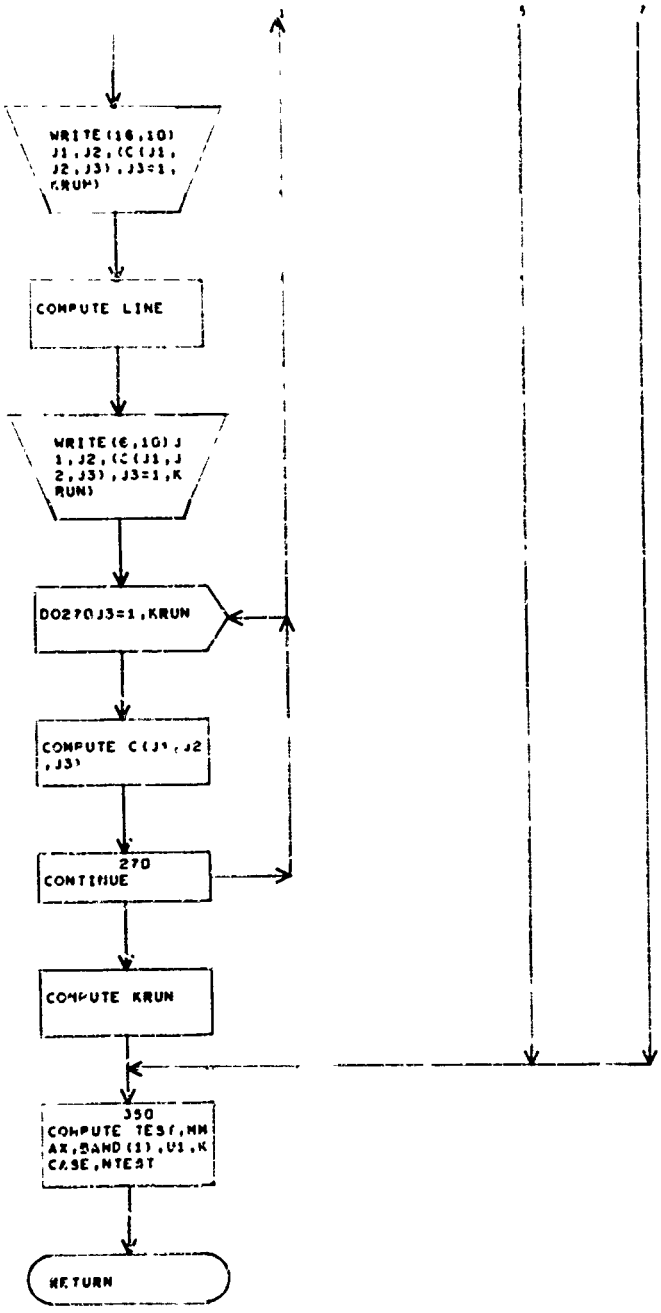

DO 214 I2=2,NMAX
DO 213 NO1=1,KRUN
213
COMPUTE NUU(NO1)
COMPUTE NUM(I2)
214
CONTINUE
COMPUTE LINE
WRITE(10,91)
(BAND(J11),J
11=1,KRUN)
WRITE(10,92)
(HIP(J11),J1
1=1,KRUN)
WRITE(10,94)
(TOL(J11),J1
1=1,KRUN)
3
4
7
4
7


WRITE(10,90)
(RL(J11),J11
=1,KRUN)
DO220J1=1,MMAX
WRITE(16,100
)
WRITE(16,100
)
COMPUTE ITA
DO220J2=1,ITA
WRITE(10,10)
J1,J2,(C(J1,
J2,J3),J3=1,
KRUN)
DO220J3=1,KRUN


COMPUTE C(J1,J2
,J3)
250
CONTINUE
230
COMPUTE KRUM
WRITE(16,100
)
WRITE(16,100
)
COMPUTE U2,NTX
WRITE(16,806
)NTX,U2
WRITE(16,100
)


WRITE(10,100
)
COMPUTE NUM(1)
IF(NMAX-1)26
6,266,262
DO264I2=2,NMAX
DO263:NO1=1,KRUN
263
COMPUTE NUU(NO1
)
COMPUTE NUM(I2)
264
CONTINUE
COMPUTE LINE
5
7


WRITE(16,91)
(BANR(J11),J
11=1,KRUN)
WRITE(16,98)
(REP(J11),J1
1=1,KRUN)
WRITE(16,94)
(TOL(J11),J1
1=1,KRUN)
DO 70 J1=1,NMAX
WRITE(16,100
)
WRITE(16,100
)
COMPUTE ITA
DO 80 J2=1,ITA


WRITE(16,10) J1,J2,(C(J1,J2,J3),J3=1,KRUN)
COMPUTE LINE
WRITE(6,10) J1,J2,(C(J1,J2,J3),J3=1,KRUN)
DO270J3=1,KRUN
COMPUTE C(J1,J2,J3)
270 CONTINUE
COMPUTE KRUN
350 COMPUTE TEST,HMAX,BAND(1),U1,KCASE,NTEST
RETURN

Section 4. SAMPLE APPLICATIONS

Example A
Type 1 Data

If it is desired to design a 17:1 bandwidth, -3 db-coupler, which has a normalized Zoe ± 1.8343 limitation on it, one needs the Chebyshev antenna distributions for 15 elements at 19.6 db side lobes:

1.0, 0.962, 0.890, 0.789, 0.663, 0.536, 0.837

Assuming that three iterations are allowed (1% tolerance (.01) is desired) and that neither development (IDEV=0) nor printed performance (XPRINT=0) data are required, then the punched input data cards are as shown in Fig. 1. The total output data is shown in Fig. 2, 3, and 4.

The computer execution time was 5.93 seconds.

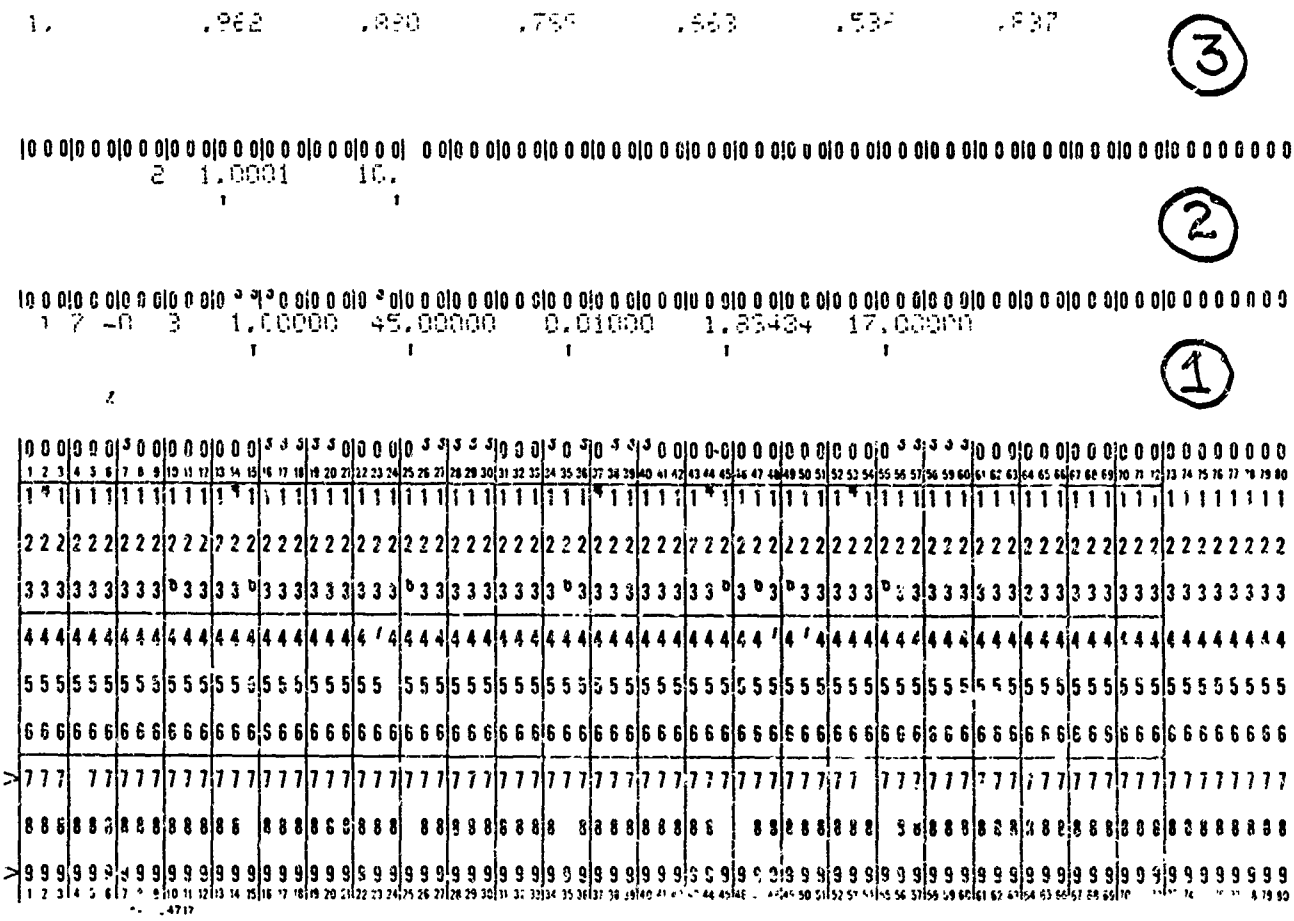


FIG. 1. Input Data Cards.[2]

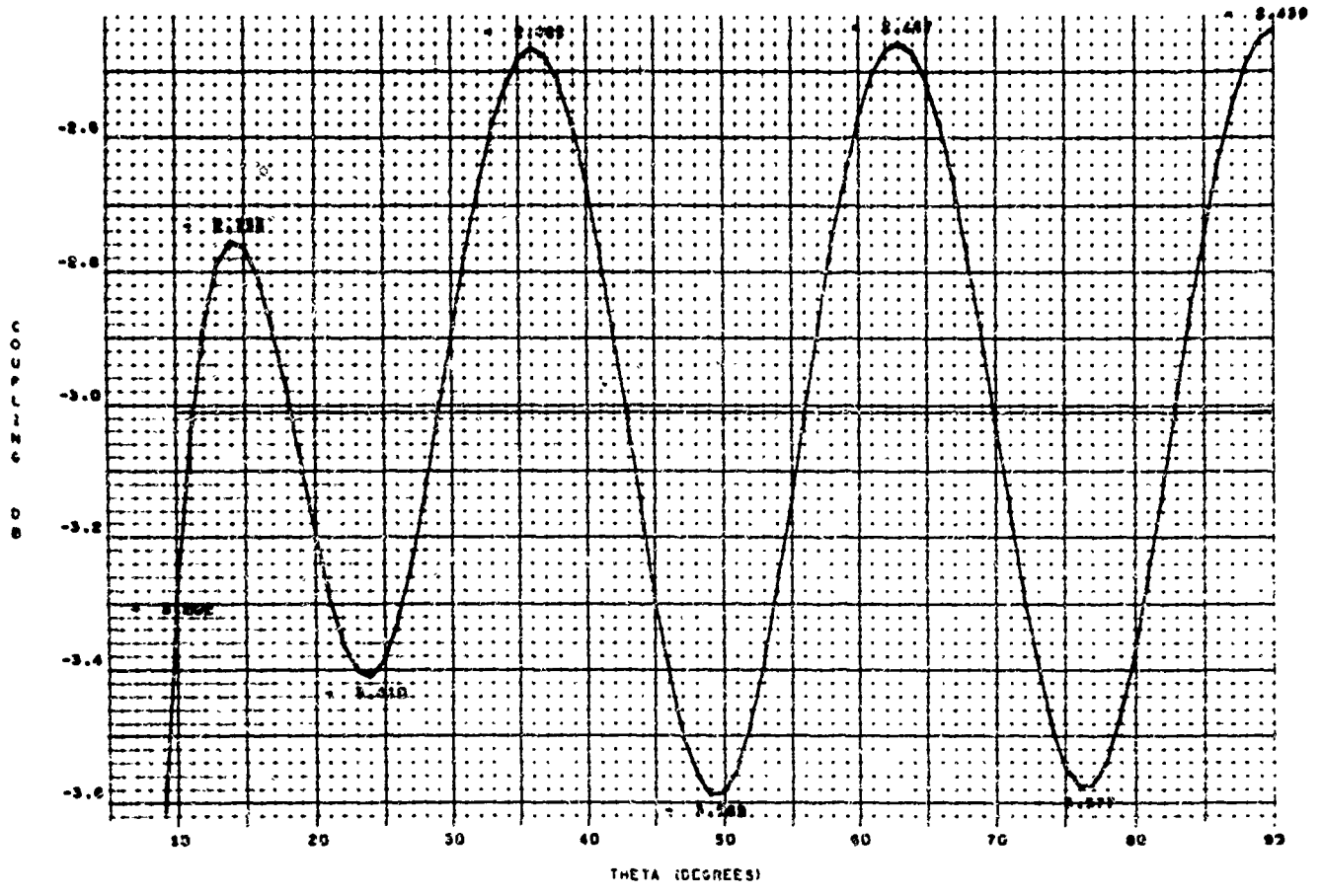
[2]Assuming this to be the first design problem for the machine, then these input data would be preceded by five cards:

1) Instable B's
2) Failed
3)
4) Theta (degrees)
5) Coupling (db)

with the reference

12345 ------ 0 5 0 5 0

Note - Card 3 was left blank since the plots (see Fig. 6, 7, and 8) were not desired to be titled on the top.



17.000 TO 1.0 BANDWIDTH COUPLER

1.02434	1.03434	1.04797	1.36001	1.23440	1.14520	1.08948
0.94178	0.94178	0.46175	0.31139	0.20792	0.13475	0.08949

1.03434	1.22380
0.94178	0.19826

1.03434
0.94178

1.01247
0.01239

FIG. 2. Response Curve and Design of Coupler.

```
      EXIT 1  IMPEDANCES ARE LESS THAN 1.0
      EXIT 2  TOO MANY PEAKS/VALLEYS IN RESPONSE CURVE
      EXIT 3  TOO FEW PEAKS/VALLEYS FOR ERROR ANALYSIS
      EXIT 4  DESIGN OF PHASE SHIFTER NOW COMPLETED
      EXIT 5  DESIGN OF COUPLER NOW COMPLETED
      EXIT 6  DESIGN OF COUPLER USED MAX. ALLOWABLE ITERATIONS
      EXIT 7  DESIGN OF PHASE SHIFTER USED MAX. ALLOW. ITERATIONS
      EXIT 8  A PEAK AND VALLEY ARE BEYOND BANDWIDTH EDGE

 UO = 45.0000    BW =17.000    ZMAX = 1.83434    TOLERANCE= 0.01000    THE MAX. ALLOWABLE ITERATION(S) ARE = 3
      GAMMA( 1, 1 ) =  0.43412
      GAMMA( 1, 2 ) =  0.20881
      GAMMA( 1, 3 ) =  0.12879
      GAMMA( 1, 4 ) =  0.08563
      GAMMA( 1, 5 ) =  0.05756
      GAMMA( 1, 6 ) =  0.03878
      GAMMA( 1, 7 ) =  0.05191

                  Γ's before maximum coupling restriction (Z max) is considered.

   Z( 1, 1 )= 1.83434    GAMMA ( 1, 1 )=.          COUPLING = 0.54179
   Z( 1, 2 )= 1.83434    GAMMA ( 1, 2 )=.          COUPLING = 0.54179
   Z( 1, 3 )= 1.83434    GAMMA ( 1, 3 )=.06901     COUPLING = 0.54179
   Z( 1, 4 )= 1.59751    GAMMA ( 1, 4 )=.08563     COUPLING = 0.43695
   Z( 1, 5 )= 1.34550    GAMMA ( 1, 5 )=.05756     COUPLING = 0.28835
   Z( 1, 6 )= 1.19903    GAMMA ( 1, 6 )=.03878     COUPLING = 0.17954
   Z( 1, 7 )= 1.10950    GAMMA ( 1, 7 )=.05191     COUPLING = 0.10354
   Z( 2, 1 )= 1.83434    GAMMA ( 2, 1 )=.03155     COUPLING = 0.54179
   Z( 2, 2 )= 1.72213    GAMMA ( 2, 2 )=.20881     COUPLING = 0.49568
   Z( 2, 3 )= 1.12716    GAMMA ( 2, 3 )=.05978     COUPLING = 0.11914
   Z( 3, 1 )= 1.83434    GAMMA ( 3, 1 )=.29637     COUPLING = 0.54179
   Z( 4, 1 )= 1.24266    GAMMA ( 4, 1 )=.10820     COUPLING = 0.21340

                                                   This section shows  0
                                                     1.  Zoe's per tandem device
                                                     2.  Γ's per tandem device
                                                     3.  Voltage-coupling coeff.
                                                         per section per tandem
                                                         coupler/phase shifter

   VAL( 1)=   56.15720  ←→ Response at lower band edge  →Typically,
   VAL( 2)=   44.44336    Relative minima in response curve (in degrees for      First subscript for which tandem coupler
   VAL( 3)=   35.74314    phase shifters; in "degree" coupling for couplers)     phase shifter.
   VAL( 4)=   30.03631                                                           Second subscript for which section in
   PEAK( 1) =  59.48249                                                          that tandem coupler/phase shifter
   PEAK( 2) =  47.91320   Relative maxima in response curve
   PEAK( 3) =  40.65406
   PEAK( 4) =  37.66095
     1.39781 |  1.28228
     1.71514 |  1.28228
     0.08521 |  1.28228
     0.41990 |  1.28228   Average ripple in response curve
     1.69918 |  1.28228
     0.71119 |  1.28228   The amount that the response curve should be shifted at
     3.00077 |  1.28228   proper θ's so that relative maximum and minimum response
     1.26905 |  1.28228   values become "equal ripple".
   B( 1 )= 8.56393
   B( 3 )=-6.03899
   B( 5 )=-4.09009
   B( 7 )=-2.82457   Fourier coefficients of error curve.  Note that also higher than the last usable harmonic is
   B( 9 )=-2.32504   calculated (for special reference).
   B(11 )=-1.51086
   B(13 )= 1.08131
   B(15 )=-2.98318
   0 1
   0 0
      CAUTIOUS ERROR CORRECTION ( 0.500X)    (Error correction in this case (.500X) operates only with 50% of what B's, above,
      GAMMA(1, 1 ) =  0.47149                 suggested.
      GAMMA(1, 2 ) =  0.18246
      GAMMA(1, 3 ) =  0.11094
      GAMMA(1, 4 ) =  0.07331
      GAMMA(1, 5 ) =  0.04742
      GAMMA(1, 6 ) =  0.03219
      GAMMA(1, 7 ) =  0.05663
```

FIG. 3. "Written" Machine Output.

```
Z( 1, 1 )= 1.83434      GAMMA ( 1, 1 )=.          COUPLING = 0.54179
Z( 1, 2 )= 1.83434      GAMMA ( 1, 2 )=.          COUPLING = 0.54179
Z( 1, 3 )= 1.83434      GAMMA ( 1, 3 )=.09329     COUPLING = 0.54179
Z( 1, 4 )= 1.52129      GAMMA ( 1, 4 )=.07331     COUPLING = 0.39656
Z( 1, 5 )= 1.31349      GAMMA ( 1, 5 )=.04742     COUPLING = 0.26612
Z( 1, 6 )= 1.19456      GAMMA ( 1, 6 )=.03219     COUPLING = 0.17593
Z( 1, 7 )= 1.12005      GAMMA ( 1, 7 )=.05663     COUPLING = 0.11289
Z( 2, 1 )= 1.83434      GAMMA ( 2, 1 )=.10082     COUPLING = 0.54179
Z( 2, 2 )= 1.49835      GAMMA ( 2, 2 )=.18246     COUPLING = 0.38368
Z( 2, 3 )= 1.03594      GAMMA ( 2, 3 )=.01765     COUPLING = 0.03529
Z( 3, 1 )= 1.83434      GAMMA ( 3, 1 )=.29437     COUPLING = 0.54179
Z( 4, 1 )= 1.16521      GAMMA ( 4, 1 )=.07630     COUPLING = 0.15172
VAL( 1)=   51.08599
VAL( 2)=   43.43703
VAL( 3)=   37.97557
VAL( 4)=   35.22722
PEAK( 1) =   53.99906
PEAK( 2) =   49.13146
PEAK( 3) =   46.52244
PEAK( 4) =   44.51455
  0.83089   0.76460
  1.16935   0.76460
  0.24353   0.76460
  0.58318   0.76460
  1.20760   0.76460
  0.23912   0.76460
  1.76889   0.76460
  0.07422   0.76460
B( 1 )= 3.48228
B( 3 )=-2.10427
B( 5 )=-2.12313
B( 7 )=-1.89765
B( 9 )=-1.25150
B(11 )=-0.74873
B(13 )=-0.67101
B(15 )=-0.76311
0 1
0 0
     NORMAL ERROR CORRECTION <------> Error correction by 100% of what B's, above, suggested.
     GAMMA( 1, 1 ) =  0.50188
     GAMMA( 1, 2 ) =  0.15537
     GAMMA( 1, 3 ) =  0.09241
     GAMMA( 1, 4 ) =  0.05679
     GAMMA( 1, 5 ) =  0.03650
     GAMMA( 1, 6 ) =  0.02566
     GAMMA( 1, 7 ) =  0.05077
Z( 1, 1 )= 1.83434      GAMMA ( 1, 1 )=.          COUPLING = 0.54179
Z( 1, 2 )= 1.83434      GAMMA ( 1, 2 )=.04080     COUPLING = 0.54179
Z( 1, 3 )= 1.69052      GAMMA ( 1, 3 )=.09241     COUPLING = 0.48158
Z( 1, 4 )= 1.40450      GAMMA ( 1, 4 )=.05679     COUPLING = 0.32719
Z( 1, 5 )= 1.25355      GAMMA ( 1, 5 )=.03650     COUPLING = 0.22221
Z( 1, 6 )= 1.16527      GAMMA ( 1, 6 )=.02566     COUPLING = 0.15177
Z( 1, 7 )= 1.10697      GAMMA ( 1, 7 )=.05077     COUPLING = 0.10128
Z( 2, 1 )= 1.83434      GAMMA ( 2, 1 )=.18607     COUPLING = 0.54179
Z( 2, 2 )= 1.25879      GAMMA ( 2, 2 )=.11457     COUPLING = 0.22617
Z( 3, 1 )= 1.83434      GAMMA ( 3, 1 )=.29437     COUPLING = 0.54179
Z( 4, 1 )= 1.04381      GAMMA ( 4, 1 )=.02144     COUPLING = 0.04285
VAL( 1)=   44.43601
VAL( 2)=   42.24631
VAL( 3)=   40.21686
VAL( 4)=   40.98947
PEAK( 1) =   47.41599
PEAK( 2) =   49.83838
PEAK( 3) =   49.89015
PEAK( 4) =   50.09895
```

FIG. 3. (Continued)

```
  0.08604   0.54705
  0.35123   0.54705
  0.43819   0.54705
  0.67476   0.54705
  0.78932   0.54705
  0.67627   0.54705
  0.65268   0.54705
  0.70794   0.54705
B( 1 )=-0.19122
B( 3 )=-0.13889
B( 5 )=-0.44933
B( 7 )=-0.12524
B( 9 )= 0.11318
B(11 )=-0.08311
B(13 )=-0.91037
B(15 )=-0.20937
0 1
0 0
     NORMAL ERROR CORRECTION
  GAMMA( 1, 1 ) =  0.50021
  GAMMA( 1, 2 ) =  0.15416
  GAMMA( 1, 3 ) =  0.08849
  GAMMA( 1, 4 ) =  0.05570
  GAMMA( 1, 5 ) =  0.03749
  GAMMA( 1, 6 ) =  0.02493
  GAMMA( 1, 7 ) =  0.04283
Z( 1, 1 )= 1.83434        GAMMA ( 1, 1 )=.        COUPLING = 0.54179
Z( 1, 2 )= 1.83434        GAMMA ( 1, 2 )=.05352   COUPLING = 0.54179
Z( 1, 3 )= 1.64797        GAMMA ( 1, 3 )=.08849   COUPLING = 0.46176
Z( 1, 4 )= 1.38001        GAMMA ( 1, 4 )=.05570   COUPLING = 0.31140
Z( 1, 5 )= 1.23440        GAMMA ( 1, 5 )=.03749   COUPLING = 0.20752
Z( 1, 6 )= 1.14520        GAMMA ( 1, 6 )=.02493   COUPLING = 0.13475
Z( 1, 7 )= 1.08948        GAMMA ( 1, 7 )=.04283   COUPLING = 0.08550
Z( 2, 1 )= 1.83434        GAMMA ( 2, 1 )=.19964   COUPLING = 0.54179
Z( 2, 2 )= 1.22380        GAMMA ( 2, 2 )=.10064   COUPLING = 0.19926
Z( 3, 1 )= 1.83434        GAMMA ( 3, 1 )=.29437   COUPLING = 0.54179
Z( 4, 1 )= 1.01247        GAMMA ( 4, 1 )=.00620   COUPLING = 0.01259
VAL( 1)=   43.25768
VAL( 2)=   42.47450
VAL( 3)=   41.41489
VAL( 4)=   41.48553
PEAK( 1) =   46.74080
PEAK( 2) =   48.83987
PEAK( 3) =   48.90138
PEAK( 4) =   49.04091
  0.27233   0.46793
  0.25604   0.46793
  0.40025   0.46793
  0.54474   0.46793
  0.57901   0.46793
  0.55288   0.46793
  0.56685   0.46793
  0.57128   0.46793
   THE DESIGN DOES NOT MEET THE SPECIFICATIONS -- FAIL
                                        EXIT BY 6
```

FIG. 3. End.

```
 1 7 -0  3   1.00000  45.00000   0.01000   1.83434  17.00000
   0.50021   0.15416   0.08849   0.05570   0.03749   0.02493   0.04283
      FOR REFERENCE
1234567890123450 5 0 5 0 5 0 5 0 5 012
```

FIG. 4. Punched Output Data.

Example B
Type 2 Data

To improve further on a coupler design, one on which data are available but in terms of reflection coefficients (such data are part of the output from previous calculations; e.g., Fig. 4), assume that the data are as in Fig. 5 below:

$\Gamma_1 = 0.4989$, $\Gamma_2 = 0.1536$, $\Gamma_3 = 0.0881$, $\Gamma_4 = 0.0575$,

$\Gamma_5 = 0.0403$, $\Gamma_6 = 0.0277$, $\Gamma_7 = 0.0303$,

with six allowable iterations, required development data, and 1% tolerance, the input data will then be as shown in Fig. 6.

The output data for this computation are shown in Fig. 7–11.

The computer execution time was 6.30 seconds.

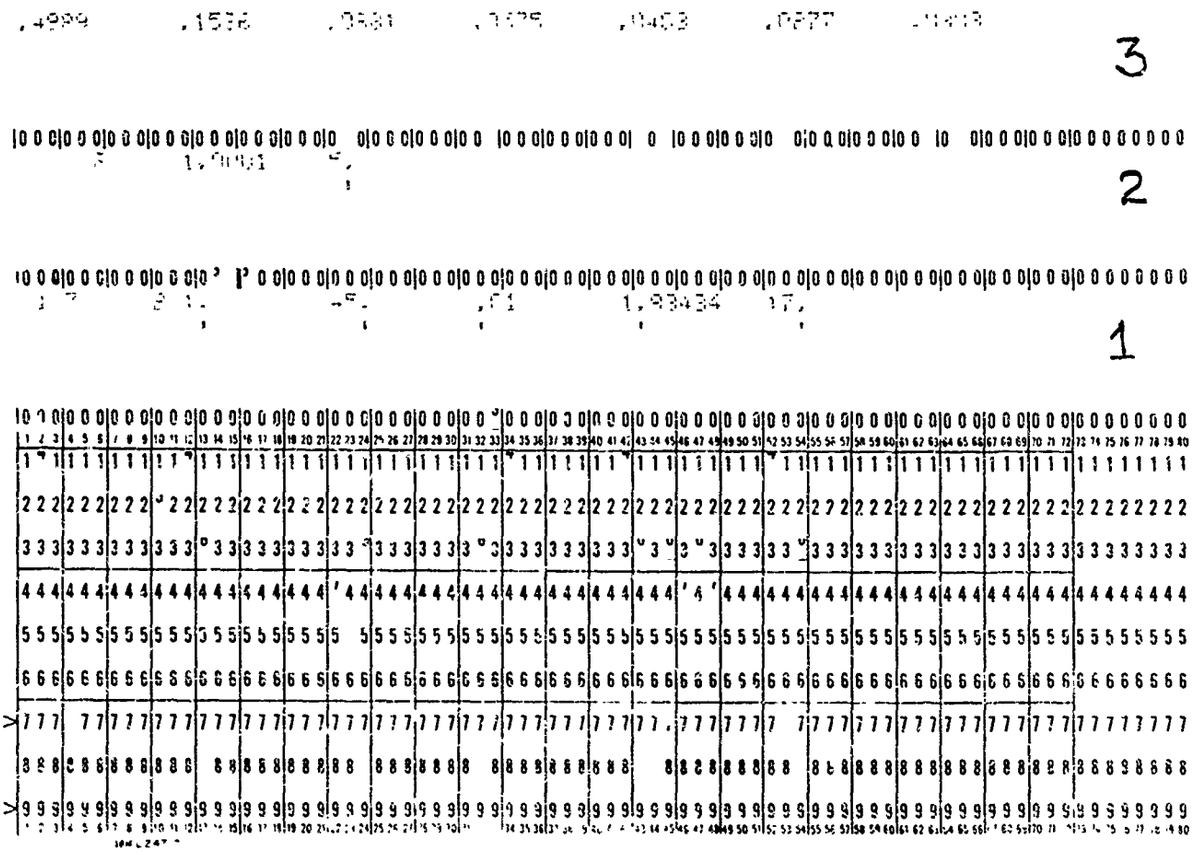
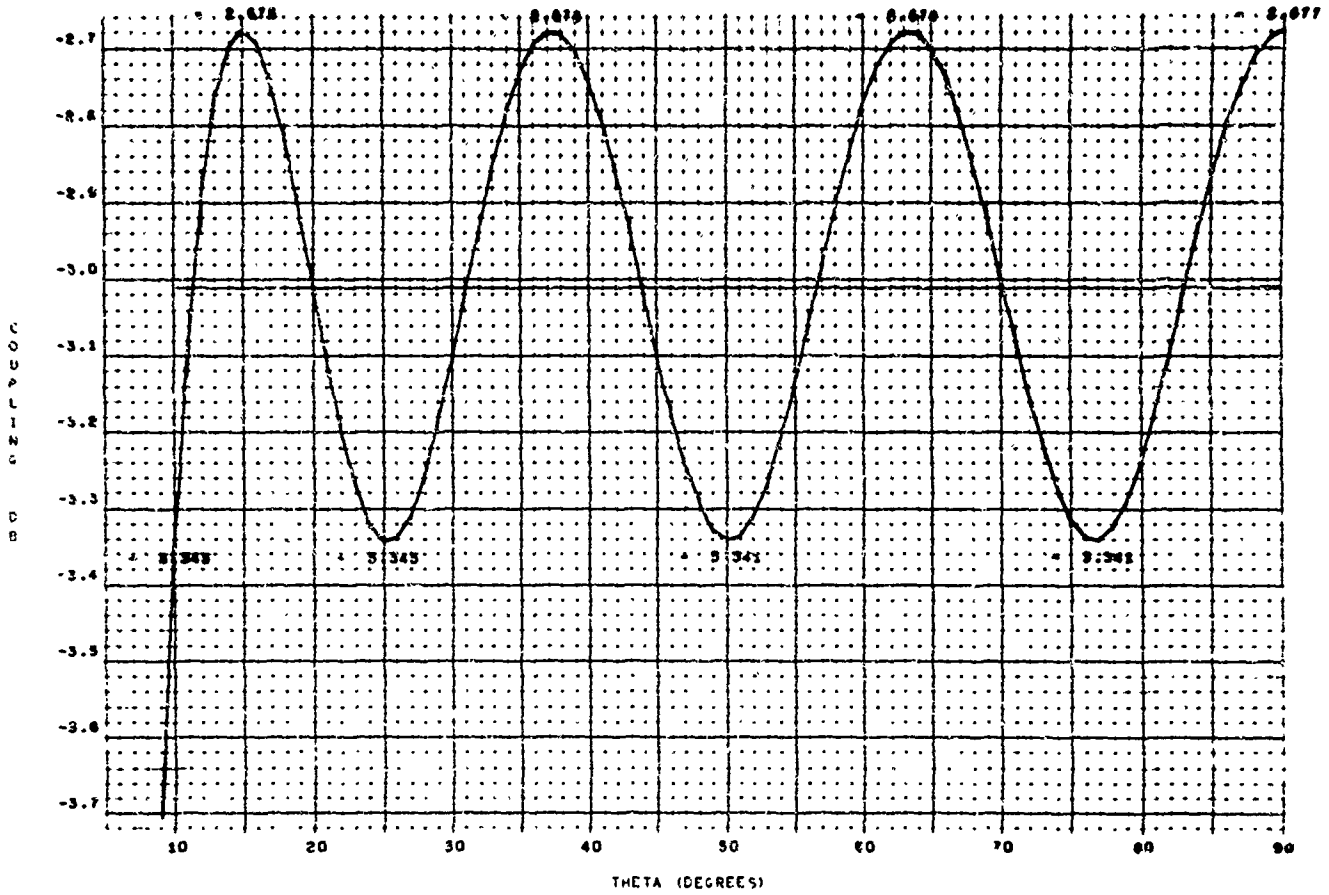


FIG. 5. Input Data Cards.



17.000 TO 1.0 BANDWIDTH COUPLER

1.83434 1.82434 1.62917 1.36591 1.21737 1.12308 1.06254
0.54178 0.54178 0.45287 0.30209 0.18419 0.11555 0.06059

1.83434 1.20888
0.54178 0.18743

1.83029
0.54022

FIG. 6. Response Curve and Design of Coupler.

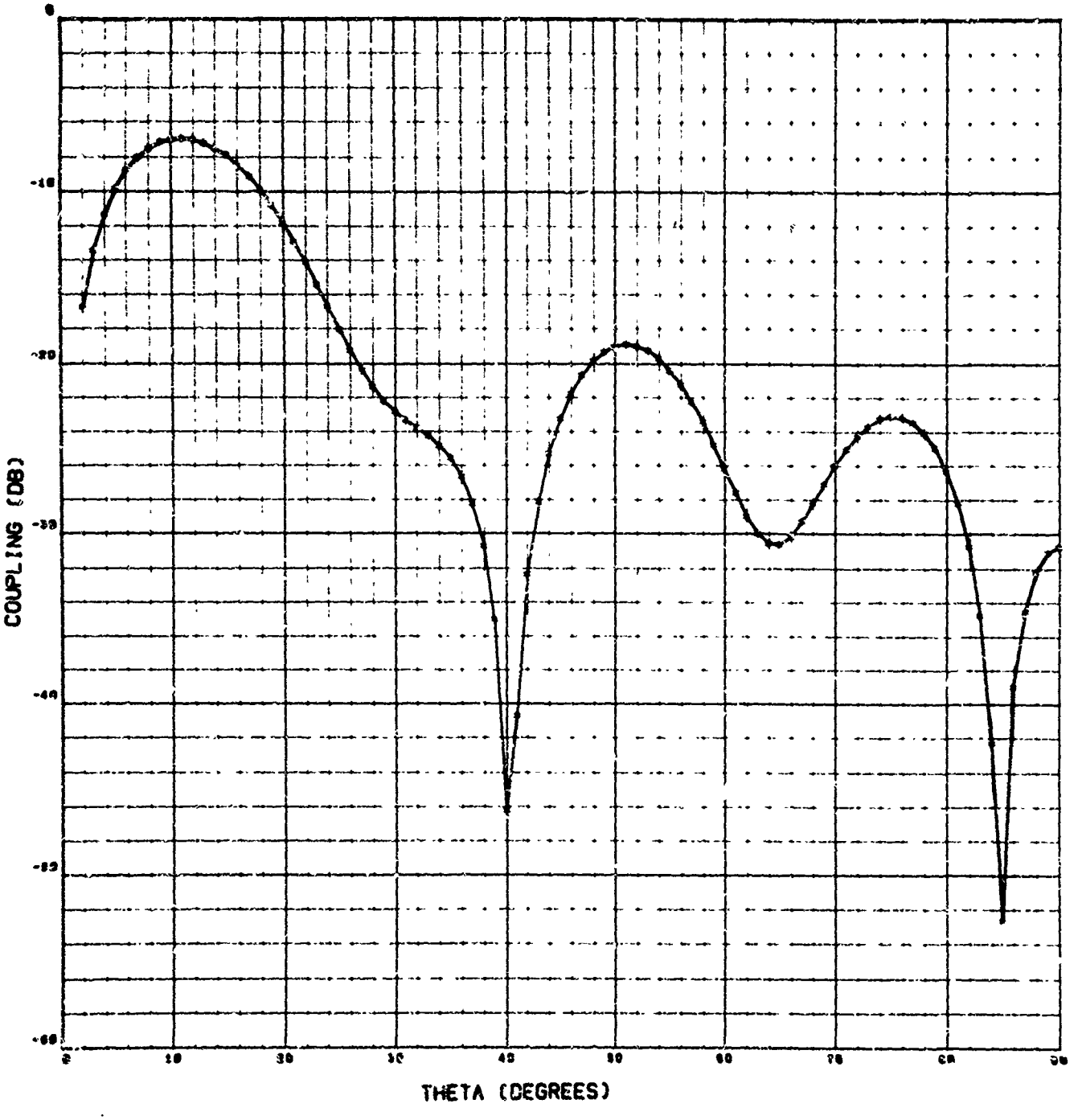


FIG. 7. Response Curve of First Tandem Coupler of Solution.

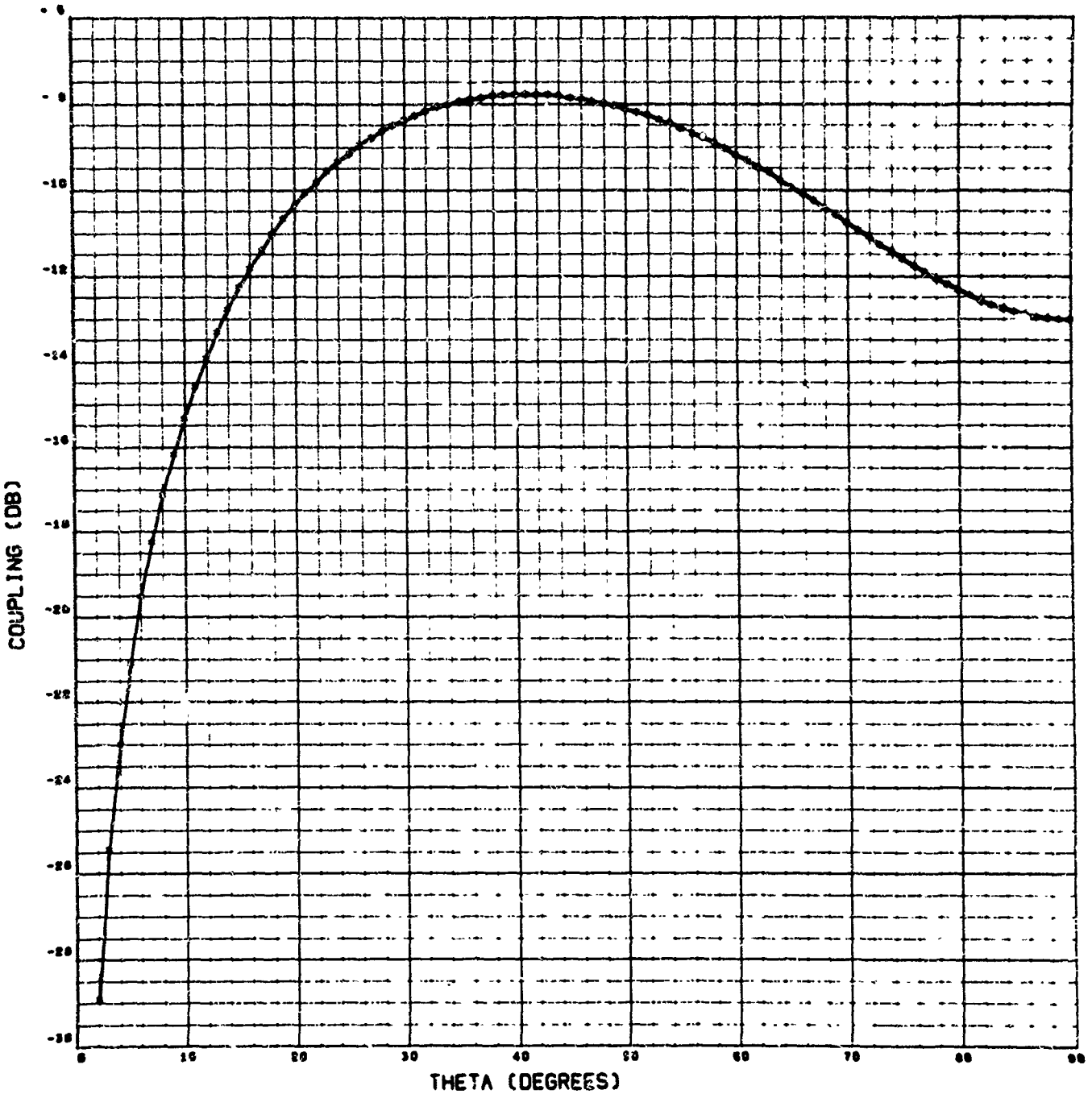


FIG. 8. Response Curve of Second Tandem Coupler of Solution.

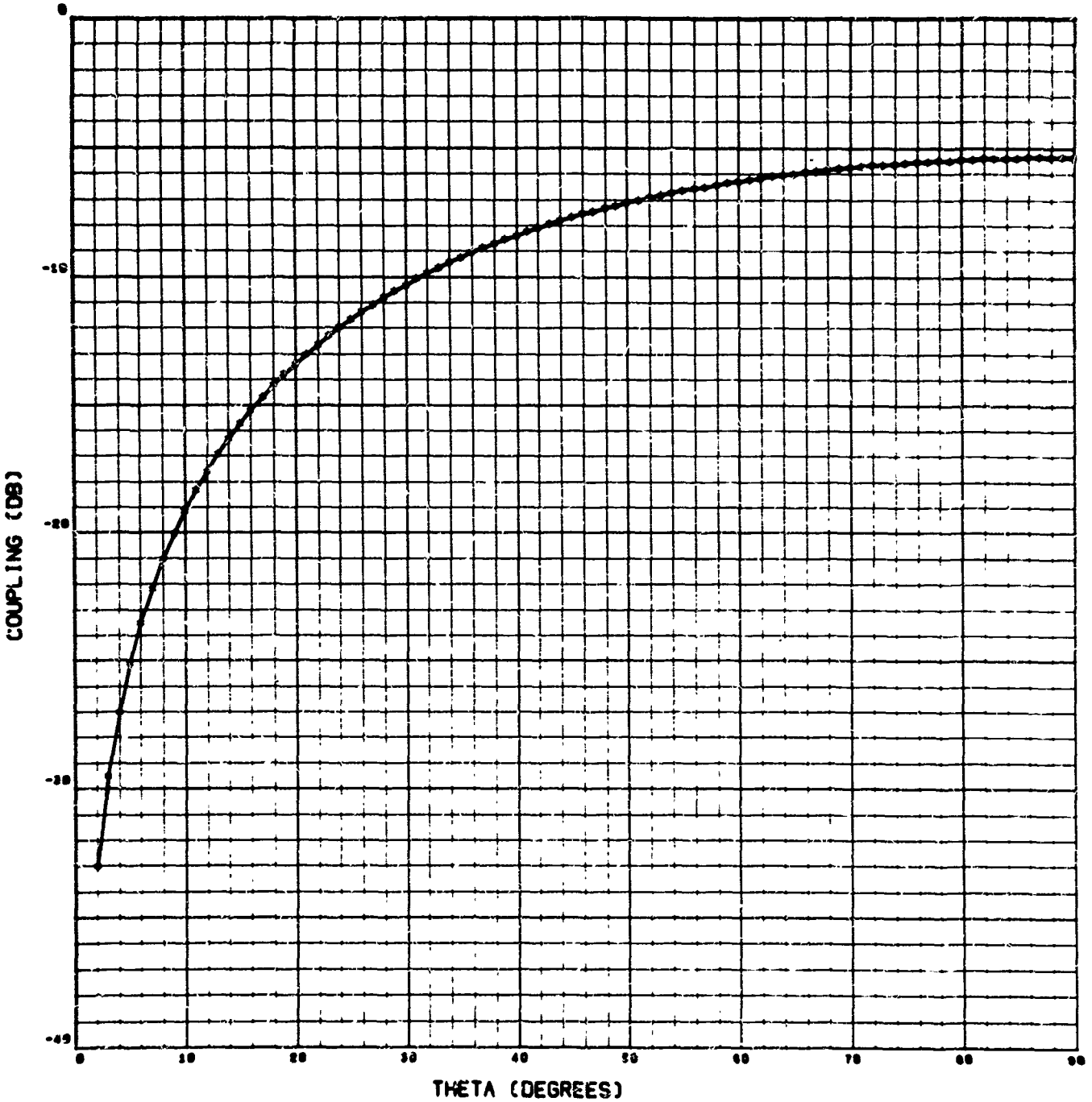


FIG. 9. Third Tandem Coupler's Response.

```
JO = 45.0000    BW =17.000    ZMAX = 1.83434    TLLERANCE=  0.01000    THE MAX. ALLOWABLE ITERATION(S) ARE =  2
     GAMMA( 1, 1 ) =  0.49890
     GAMMA( 1, 2 ) =  0.15360
     GAMMA( 1, 3 ) =  0.08810
     GAMMA( 1, 4 ) =  0.05750
     GAMMA( 1, 5 ) =  0.04030
     GAMMA( 1, 6 ) =  0.02770
     GAMMA( 1, 7 ) =  0.03030
  Z( 1, 1 )= 1.83434          GAMMA ( 1, 1 )=.          COUPLING = 0.54179
  Z( 1, 2 )= 1.83434          GAMMA ( 1, 2 )=.05904     COUPLING = 0.54179
  Z( 1, 3 )= 1.62981          GAMMA ( 1,   )=.08810     COUPLING = 0.45299
  Z( 1, 4 )= 1.36589          GAMMA ( 1, 4 )=.05750     COUPLING = 0.30208
  Z( 1, 5 )= 1.21735          GAMMA ( 1, 5 )=.04030     COUPLING = 0.19418
  Z( 1, 6 )= 1.12303          GAMMA ( 1, 6 )=.02770     COUPLING = 0.11591
  Z( 1, 7 )= 1.06249          GAMMA ( 1, 7 )=.03030     COUPLING = 0.06056
  Z( 2, 1 )= 1.83434          GAMMA ( 2, 1 )=.20553     COUPLING = 0.54179
  Z( 2, 2 )= 1.20886          GAMMA ( 2, 2 )=.09456     COUPLING = 0.18744
  Z( 3, 1 )= 1.83033          GAMMA ( 3, 1 )=.29337     COUPLING = 0.54024
  VAL( 1)=   42.88393
  VAL( 2)=   42.88560
  VAL( 3)=   42.89409
  VAL( 4)=   42.90123
  PEAK( 1) =   47.29667
  PEAK( 2) =   47.27319
  PEAK( 3) =   47.26911
  PEAK( 4) =   47.28414
    0.33294   0.33205
    0.33457   0.33205
    0.33267   0.33205
    0.33129   0.33205
    0.33128   0.33205
    0.33071   0.33205
    0.33012   0.33205
    0.33282   0.33205
  B( 1 )=-0.00209
  B( 3 )= 0.00254
  B( 5 )=-0.00433
  B( 7 )=-0.00013
  B( 9 )=-0.00282
  B(11 )=-0.00077
  B(13 )= 0.00534
  B(15 )= 0.00079
  0 1
  0 0
      CAUTIOUS ERROR CORRECTION ( 0.500X)
      GAMMA( 1, 1 ) =  0.49869
      GAMMA( 1, 2 ) =  0.15361
      GAMMA( 1, 3 ) =  0.08808
      GAMMA( 1, 4 ) =  0.05750
      GAMMA( 1, 5 ) =  0.04029
      GAMMA( 1, 6 ) =  0.02770
      GAMMA( 1, 7 ) =  0.03032
  Z( 1, 1 )= 1.83434          GAMMA ( 1, 1 )=.          COUPLING = 0.54179
  Z( 1, 2 )= 1.83434          GAMMA ( 1, 2 )=.05905     COUPLING = 0.54179
  Z( 1, 3 )= 1.62977          GAMMA ( 1, 3 )=.08808     COUPLING = 0.45298
  Z( 1, 4 )= 1.36591          GAMMA ( 1, 4 )=.05750     COUPLING = 0.30209
  Z( 1, 5 )= 1.21737          GAMMA ( 1, 5 )=.04029     COUPLING = 0.19419
  Z( 1, 6 )= 1.12308          GAMMA ( 1, 6 )=.02770     COUPLING = 0.11585
  Z( 1, 7 )= 1.06254          GAMMA ( 1, 7 )=.03032     COUPLING = 0.06059
  Z( 2, 1 )= 1.83434          GAMMA ( 2, 1 )=.20553     COUPLING = 0.54179
  Z( 2, 2 )= 1.20886          GAMMA ( 2, 2 )=.09456     COUPLING = 0.18744
```

FIG. 10. "Written" Machine Output.

```
Z( 3, 1 )= 1.83029          GAMMA ( 3, 1 )=.29336          COUPLING = 0.54022
VAL( 1)=   42.88294
VAL( 2)=   42.88415
VAL( 3)=   42.89208
VAL( 4)=   42.89609
PEAK( 1) =   47.29357
PEAK( 2) =   47.27663
PEAK( 3) =   47.27294
PEAK( 4) =   47.28145
  0.33310   0.33227
  0.33414   0.33227
  0.33291   0.33227
  0.33177   0.33227
  0.33161   0.33227
  0.33125   0.33227
  0.33056   0.33227
  0.33244   0.33227
     GAMMA( 1, 1 ) =  0.49889
     GAMMA( 1, 2 ) =  0.15361
     GAMMA( 1, 3 ) =  0.08808
     GAMMA( 1, 4 ) =  0.05750
     GAMMA( 1, 5 ) =  0.04029
     GAMMA( 1, 6 ) =  0.02770
     GAMMA( 1, 7 ) =  0.03032
Z( 1, 1 )= 1.83434          GAMMA ( 1, 1 )=.          COUPLING = 0.54179
Z( 1, 2 )= 1.83434          GAMMA ( 1, 2 )=.05905     COUPLING = 0.54179
Z( 1, 3 )= 1.62977          GAMMA ( 1, 3 )=.08808     COUPLING = 0.45298
Z( 1, 4 )= 1.36591          GAMMA ( 1, 4 )=.05750     COUPLING = 0.30209
Z( 1, 5 )= 1.21737          GAMMA ( 1, 5 )=.04029     COUPLING = 0.19419
Z( 1, 6 )= 1.12308          GAMMA ( 1, 6 )=.02770     COUPLING = 0.11555
Z( 1, 7 )= 1.06254          GAMMA ( 1, 7 )=.03032     COUPLING = 0.06059
Z( 2, 1 )= 1.83434          GAMMA ( 2, 1 )=.20553     COUPLING = 0.54179
Z( 2, 2 )= 1.20886          GAMMA ( 2, 2 )=.09456     COUPLING = 0.18744
Z( 3, 1 )= 1.83029          GAMMA ( 3, 1 )=.29336     COUPLING = 0.54022
VAL( 1)=   42.88294
VAL( 2)=   42.88415
VAL( 3)=   42.89208
VAL( 4)=   42.89609
PEAK( 1) =   47.29357
PEAK( 2) =   47.27663
PEAK( 3) =   47.27294
PEAK( 4) =   47.28145
  0.33310   0.33227
  0.33414   0.33227
  0.33291   0.33227
  0.33177   0.33227
  0.33161   0.33227
  0.33125   0.33227
  0.33056   0.33227
  0.33244   0.33227
THE DESIGN DOES MEET THE SPECIFICATIONS, AFTER  3  ITERATIONS
                                EXIT BY 5
     Z(I, I)    1.83434  1.83434
     Z(1, 2)    1.83434  1.83434
     Z(1, 3)    1.64797  1.62977
     Z(1, 4)    1.38001  1.36591
     Z(1, 5)    1.23440  1.21737
     Z(1, 6)    1.14520  1.12308
     Z(1, 7)    1.08948  1.06254
     Z(2, 1)    1.83434  1.83434
     Z(2, 2)    1.22380  1.20886
     Z(3, 1)    1.83434  1.83029
     Z(4, 1)    1.01247  ......
```

FIG. 10. End.

```
      N=13        COUPLING= -3.0103 DB          BANDWIDTH=17.000     1.834
                  RIPPLE= 0.3325   DB           TOLERANCE=0.0016
  3
  7
    1.83434   1.83434   1.62977   1.36591   1.21737   1.12308   1.06254
  2
    1.83434   1.20886
  1
    1.83029
  1 7 -0  2   1.00000  45.00000   0.01000   1.83434  17.00000
    0.49889   0.15361   0.08808   0.05750   0.04029   0.02770   0.03032

      FOR REFERENCE
123456789012345     0    5    0    5    0    5    0    5    0    5    012
```

FIG. 11.

Example C
Type 3 Data (Phase Shifter)

Let it be required to check and improve, if necessary, a phase shifter design that is in terms of even mode impedances: specifically, the 17:1 bandwidth, 90 degree phase shifter of Ref. 12. Thus, the input data are as in Fig. 12 with the output data as shown in Fig. 13-15.

The computer execution time was 2.85 seconds.

Example D
Type 3 Data (Coupler)

Entertain the request for a 7.50:1 bandwidth, -3 db, re-entrant nine-section coupler with a normalized Zoe = 4.5 for the maximum coupled section. Note Ref. 10, which contains such a coupler design, except that Zoe = 4.93133 and that the bandwidth is 7.365:1. Therefore, let this published data be the starting point of the desired data. Thus, the input data cards are prepared according to Fig. 16 with the output data shown in Fig. 17-19.

The computer execution time was 7.65 seconds.

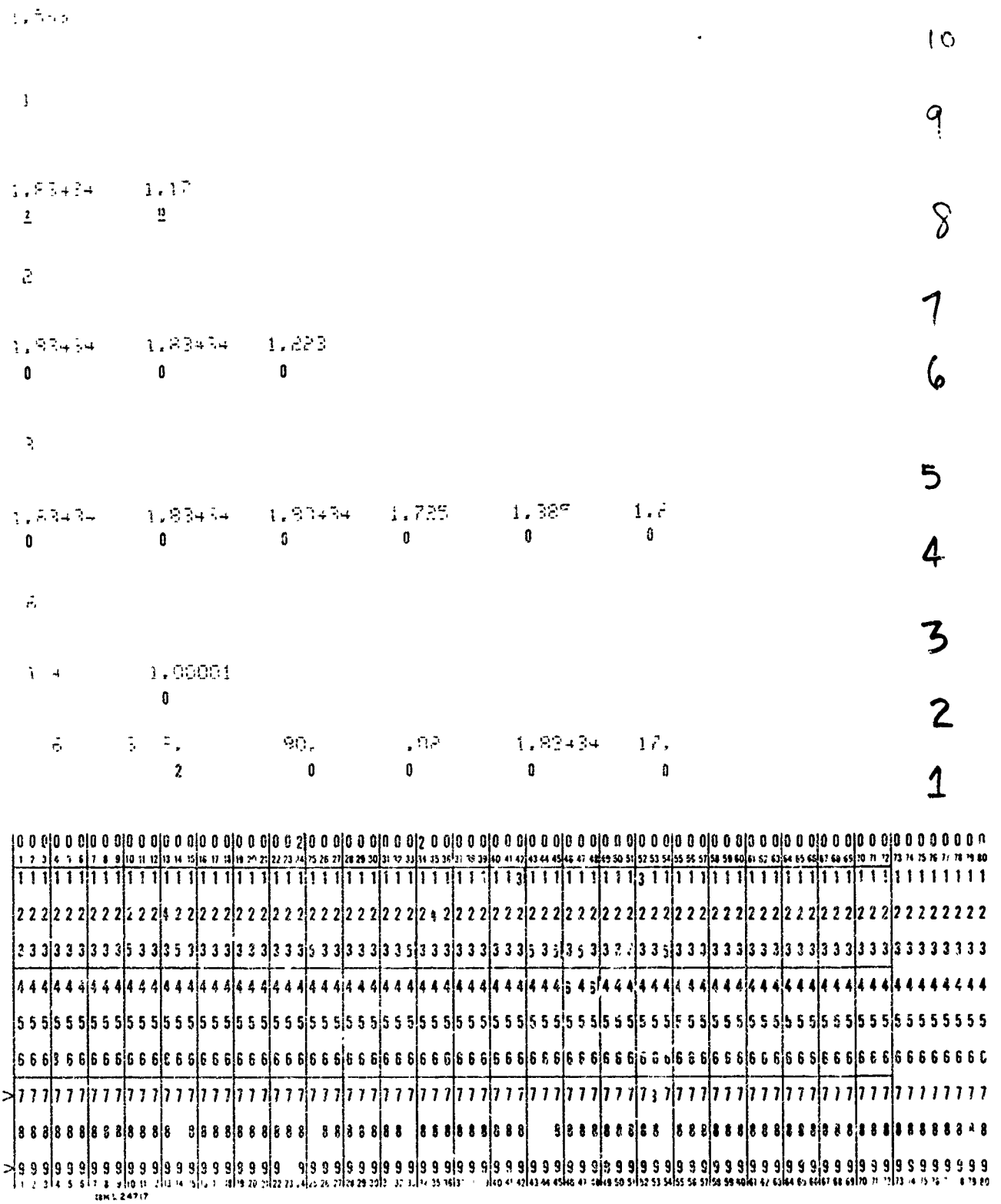
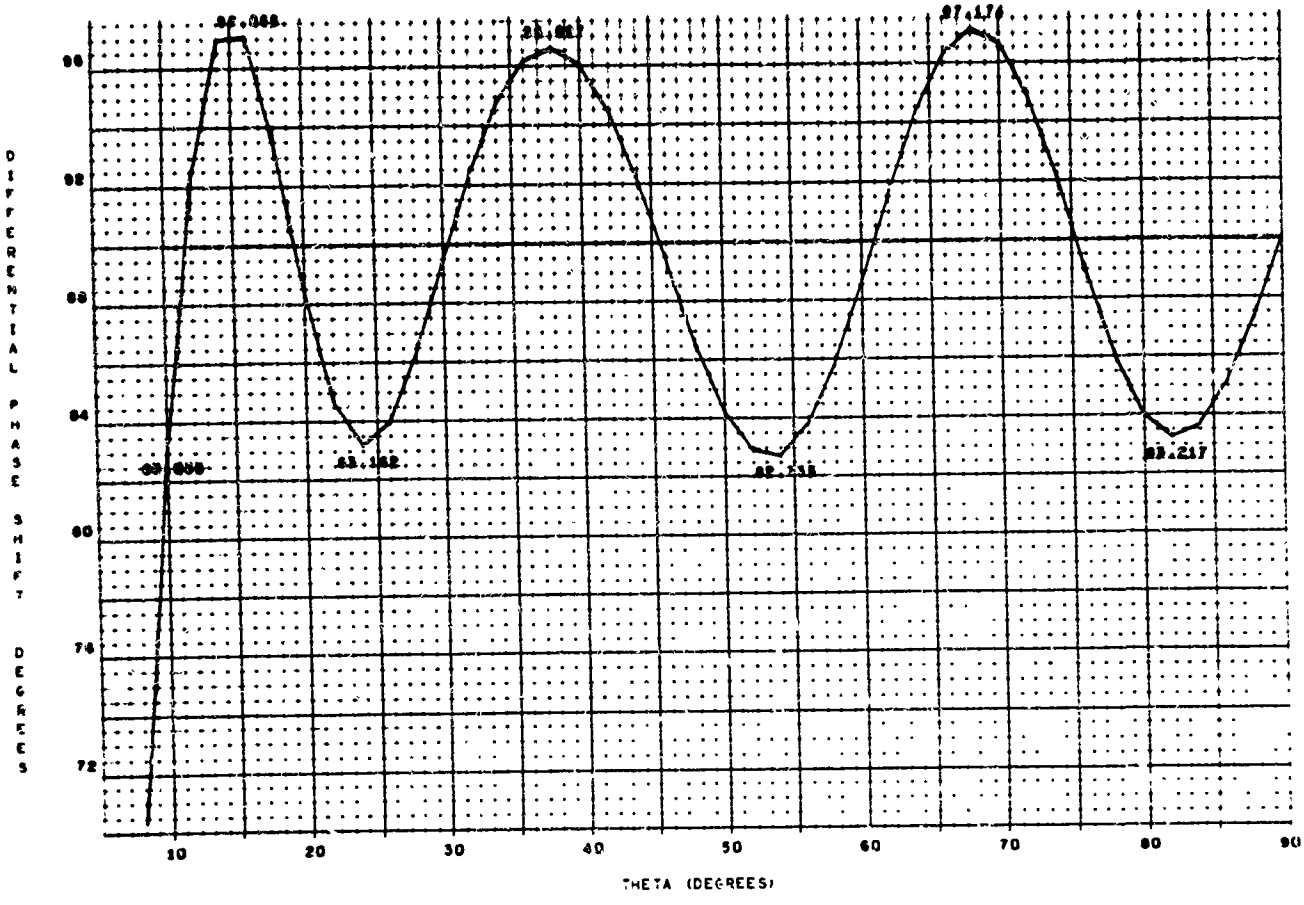


FIG. 12. Input Data Cards.



17.000 TO 1.0 BANDWIDTH PHASE SHIFTER

1.03434 1.03434 1.03434 1.03993 1.07341 1.19036
0.94178 0.94178 0.94178 0.48130 0.30705 0.17251

1.03434 1.03434 1.24892
0.94178 0.94178 0.21888

1.03434 1.18060
0.94178 0.16491

1.25408
0.41437

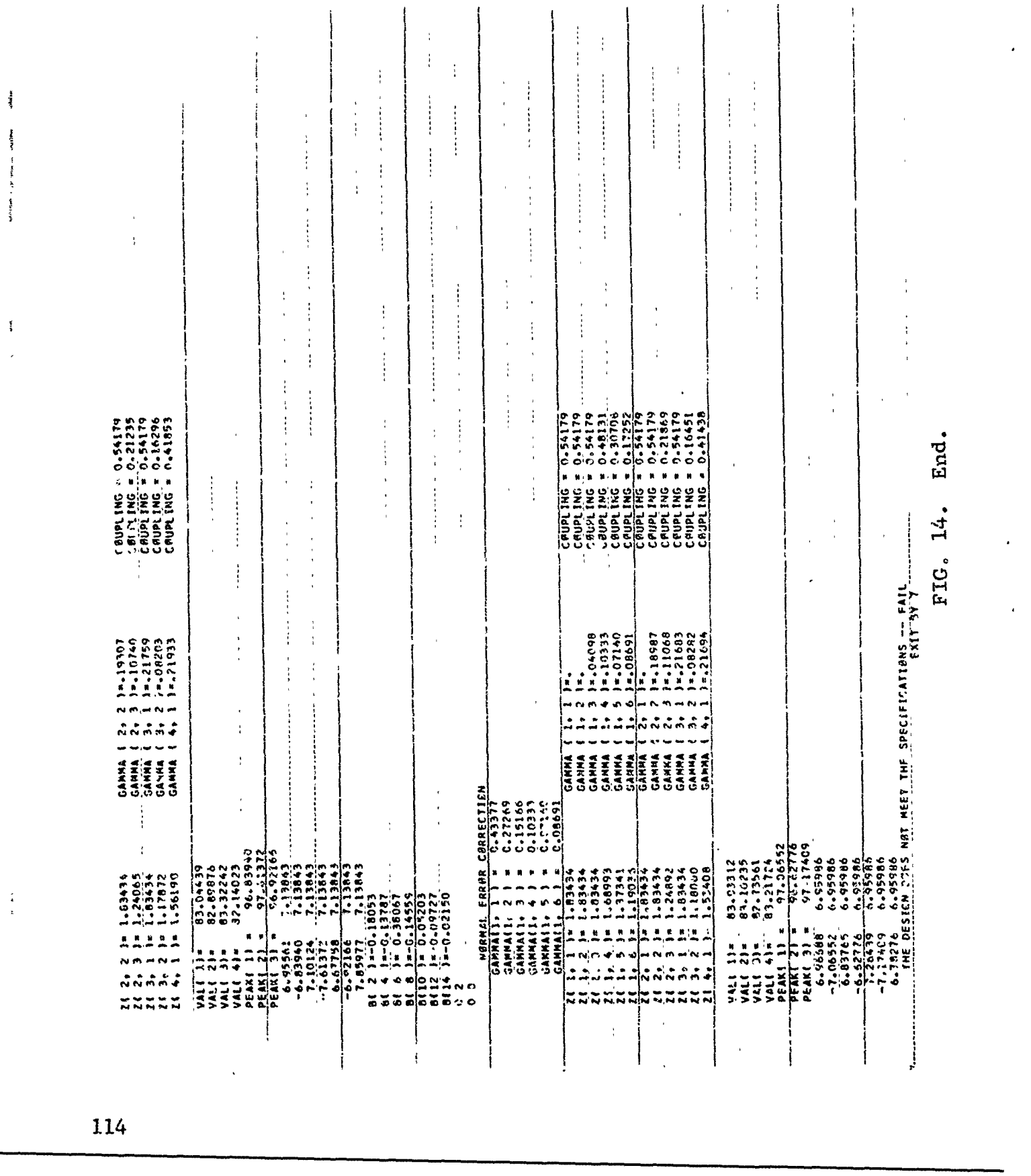
FIG. 13. Response Curve and Design of Phase Shifter.

```
U0 = 90.0000    BW =17.000    ZMAX = 1.83434    TOLERANCE= 0.02000    THE MAX. ALLOWABLE ITERATION(S) ARE =  3
  1.83434   1.83434   1.83434   1.72500   1.38500   1.20000
  1.83434   1.83434   1.22300
  1.83434   1.17000
  1.56600
    GAMMA( 1, 1 ) =  0.54170
    GAMMA( 1, 2 ) =  0.27830
    GAMMA( 1, 3 ) =  0.13103
    GAMMA( 1, 4 ) =  0.10932
    GAMMA( 1, 5 ) =  0.07157
    GAMMA( 1, 6 ) =  0.09091
Z( 1, 1 )= 1.83434        GAMMA ( 1, 1 )=.          COUPLING = 0.54179
Z( 1, 2 )= 1.83434        GAMMA ( 1, 2 )=.          COUPLING = 0.54179
Z( 1, 3 )= 1.83434        GAMMA ( 1, 3 )=.03672     COUPLING = 0.54179
Z( 1, 4 )= 1.72500        GAMMA ( 1, 4 )=.10932     COUPLING = 0.49693
Z( 1, 5 )= 1.38500        GAMMA ( 1, 5 )=.07157     COUPLING = 0.31465
Z( 1, 6 )= 1.20000        GAMMA ( 1, 6 )=.09091     COUPLING = 0.18033
Z( 2, 1 )= 1.83434        GAMMA ( 2, 1 )=.          COUPLING = 0.54179
Z( 2, 2 )= 1.83434        GAMMA ( 2, 2 )=.19996     COUPLING = 0.54179
Z( 2, 3 )= 1.22300        GAMMA ( 2, 3 )=.10031     COUPLING = 0.19863
Z( 3, 1 )= 1.83434        GAMMA ( 3, 1 )=.22113     COUPLING = 0.54179
Z( 3, 2 )= 1.17000        GAMMA ( 3, 2 )=.07834     COUPLING = 0.15573
Z( 4, 1 )= 1.56600        GAMMA ( 4, 1 )=.22058     COUPLING = 0.42069

VAL( 1)=   82.90401
VAL( 2)=   81.88882
VAL( 3)=   84.37637
VAL( 4)=   80.59766
PEAK( 1) =   96.40284
PEAK( 2) =   99.49004
PEAK( 3) =   96.03380
  7.09599   7.43712
 -6.30284   7.43712
  8.11118   7.43712
 -9.49004   7.43712
  5.62363   7.43712
 -6.03380   7.43712
  9.40234   7.43712
B( 2 )=-0.54761
B( 4 )=-0.36671
B( 6 )= 1.60211
B( 8 )=-0.39615
B(10 )=-0.12363
B(12 )=-0.26380
B(14 )=-0.18032
0 2
0 0
    CAUTIOUS ERROR CORRECTION ( 0.950X)
    GAMMA( 1, 1 ) =  0.43692
    GAMMA( 1, 2 ) =  0.27510
    GAMMA( 1, 3 ) =  0.14502
    GAMMA( 1, 4 ) =  0.10587
    GAMMA( 1, 5 ) =  0.07049
    GAMMA( 1, 6 ) =  0.08861
Z( 1, 1 )= 1.83434        GAMMA ( 1, 1 )=.          COUPLING = 0.54179
Z( 1, 2 )= 1.83434        GAMMA ( 1, 2 )=.          COUPLING = 0.54179
Z( 1, 3 )= 1.83434        GAMMA ( 1, 3 )=.03761     COUPLING = 0.54179
Z( 1, 4 )= 1.70135        GAMMA ( 1, 4 )=.10587     COUPLING = 0.48647
Z( 1, 5 )= 1.37560        GAMMA ( 1, 5 )=.07049     COUPLING = 0.30850
Z( 1, 6 )= 1.19444        GAMMA ( 1, 6 )=.08861     COUPLING = 0.17583
Z( 2, 1 )= 1.83434        GAMMA ( 2, 1 )=.          COUPLING = 0.54179
```

Normalized Zoe's of input data (arranged by tandem phase shifters).

FIG. 14. "Written" Machine Output.



```
Z( 2, 2 )= 1.63434          GAMMA ( 2, 2 )=.19307          COUPLING = 0.54179
Z( 2, 3 )= 1.24065          GAMMA ( 2, 3 )=.10740          COUPLING = 0.21235
Z( 3, 1 )= 1.83434          GAMMA ( 3, 1 )=.21759          COUPLING = 0.54179
Z( 3, 2 )= 1.17872          GAMMA ( 3, 2 )=.08203          COUPLING = 0.16296
Z( 4, 1 )= 1.56190          GAMMA ( 4, 1 )=.21933          COUPLING = 0.41853

 VALI 1)=    83.04439
 VALI 2)=    82.89876
 VALI 3)=    83.32242
 VALI 4)=    32.14023
 PEAK( 1) =  96.83940
 PEAK( 2) =  97.11372
   PEAK( 3) =  96.92165
     6.95561    7.13843
    -6.83940    7.13843
     7.10124    7.13843
    -7.61372    7.13843
     6.67758    7.13843
    -6.82166    7.13843
     7.05977    7.13843
BI 2 )=-0.18053
BI 4 )=-0.13787
BI 6 )= 0.38067
BI 8 )=-0.14559
BI10 )= 0.04203
BI12 )=-0.09727
BI14 )=-0.02150
 0 2
 0 3
        NORMAL ERROR CORRECTION
     GAMMA( 1, 1 ) =  0.43377
     GAMMA( 2, 1 ) =  0.27269
     GAMMA( 3, 1 ) =  0.15166
     GAMMA( 4, 1 ) =  0.10339
     GAMMA( 5, 1 ) =  0.07140
     GAMMA( 6, 1 ) =  0.08691
Z( 1, 1 )= 1.83434          GAMMA ( 1, 1 )=.          COUPLING = 0.54179
Z( 1, 2 )= 1.83434          GAMMA ( 1, 2 )=.          COUPLING = 0.54179
Z( 1, 3 )= 1.83434          GAMMA ( 1, 3 )=.04098     COUPLING = 0.54179
Z( 1, 4 )= 1.68993          GAMMA ( 1, 4 )=.10333     COUPLING = 0.48131
Z( 1, 5 )= 1.37341          GAMMA ( 1, 5 )=.07140     COUPLING = 0.30706
Z( 1, 6 )= 1.19035          GAMMA ( 1, 6 )=.08691     COUPLING = 0.17252
Z( 2, 1 )= 1.83434          GAMMA ( 2, 1 )=.          COUPLING = 0.54179
Z( 2, 2 )= 1.83434          GAMMA ( 2, 2 )=.18987     COUPLING = 0.54179
Z( 2, 3 )= 1.24892          GAMMA ( 2, 3 )=.11068     COUPLING = 0.21869
Z( 3, 1 )= 1.83434          GAMMA ( 3, 1 )=.21683     COUPLING = 0.54179
Z( 3, 2 )= 1.18000          GAMMA ( 3, 2 )=.08282     COUPLING = 0.16451
Z( 4, 1 )= 1.55408          GAMMA ( 4, 1 )=.21694     COUPLING = 0.41438

 VALI 1)=    83.03312
 VALI 2)=    83.16235
 VALI 3)=    82.73561
 VALI 4)=    83.21724
 PEAK( 1) =  97.06552
   PEAK( 2) =  96.82776
   PEAK( 3) =  97.17409
     6.96388    6.95986
    -7.06552    6.95986
     6.83765    6.95986
    -6.82776    6.95986
     7.26439    6.95986
    -7.17409    6.95986
     6.78276    6.95986
   THE DESIGN DOES NOT MEET THE SPECIFICATIONS -- FAIL
                                   EXIT SW 7
```

FIG. 14. End.

```
      THE DESIGN DOES NOT MEET THE SPECIFICATIONS -- FAIL
-0 6 -0  3    2.00000   90.00000    0.02000    1.83434   17.00000

     0.43377   0.27269   0.15166    0.10333    0.07140   0.08691

          FOR REFERENCE
1234567890123450 5 0 5 0 5 0 5 0 5 0 5 012
```

FIG. 15.

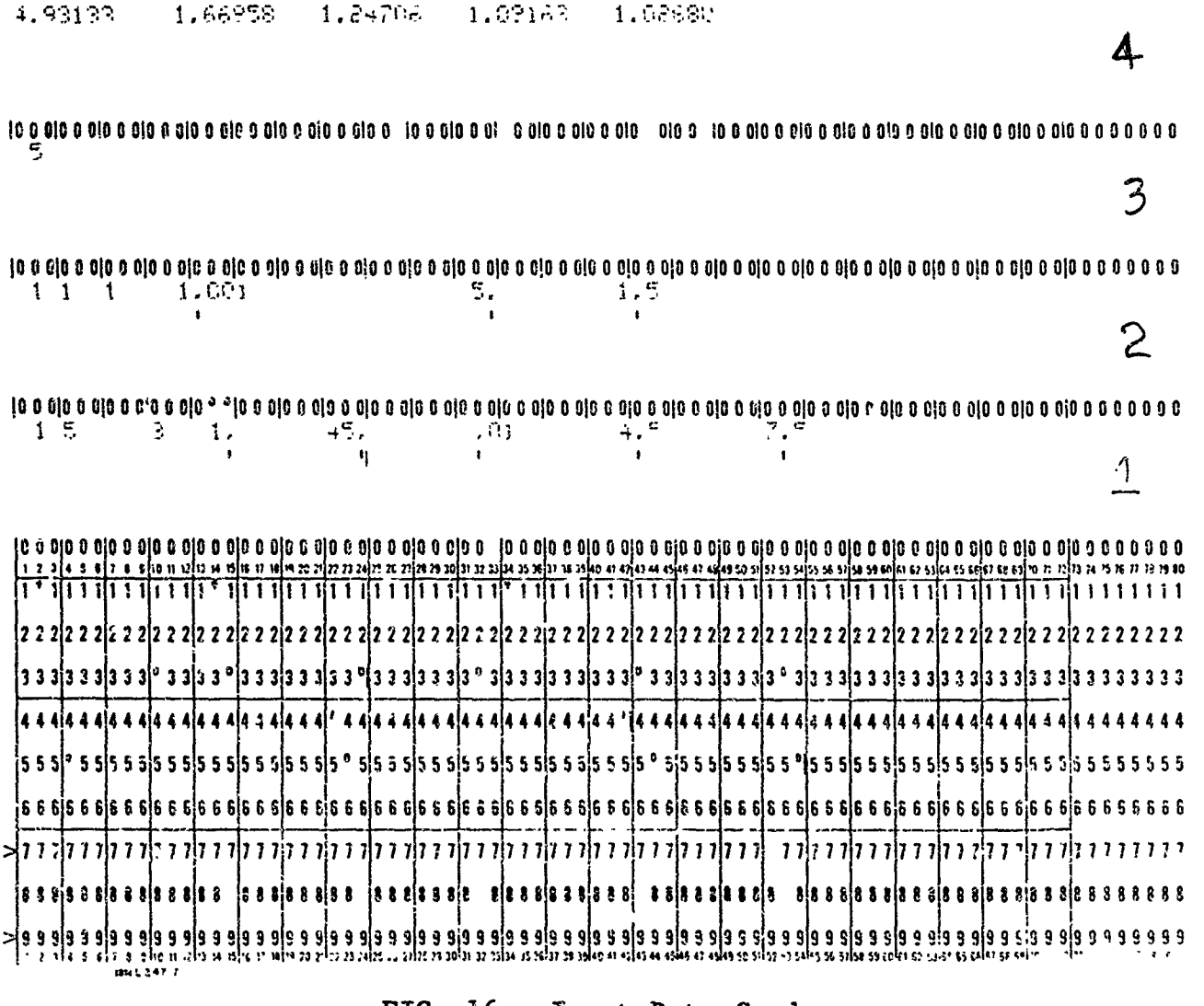
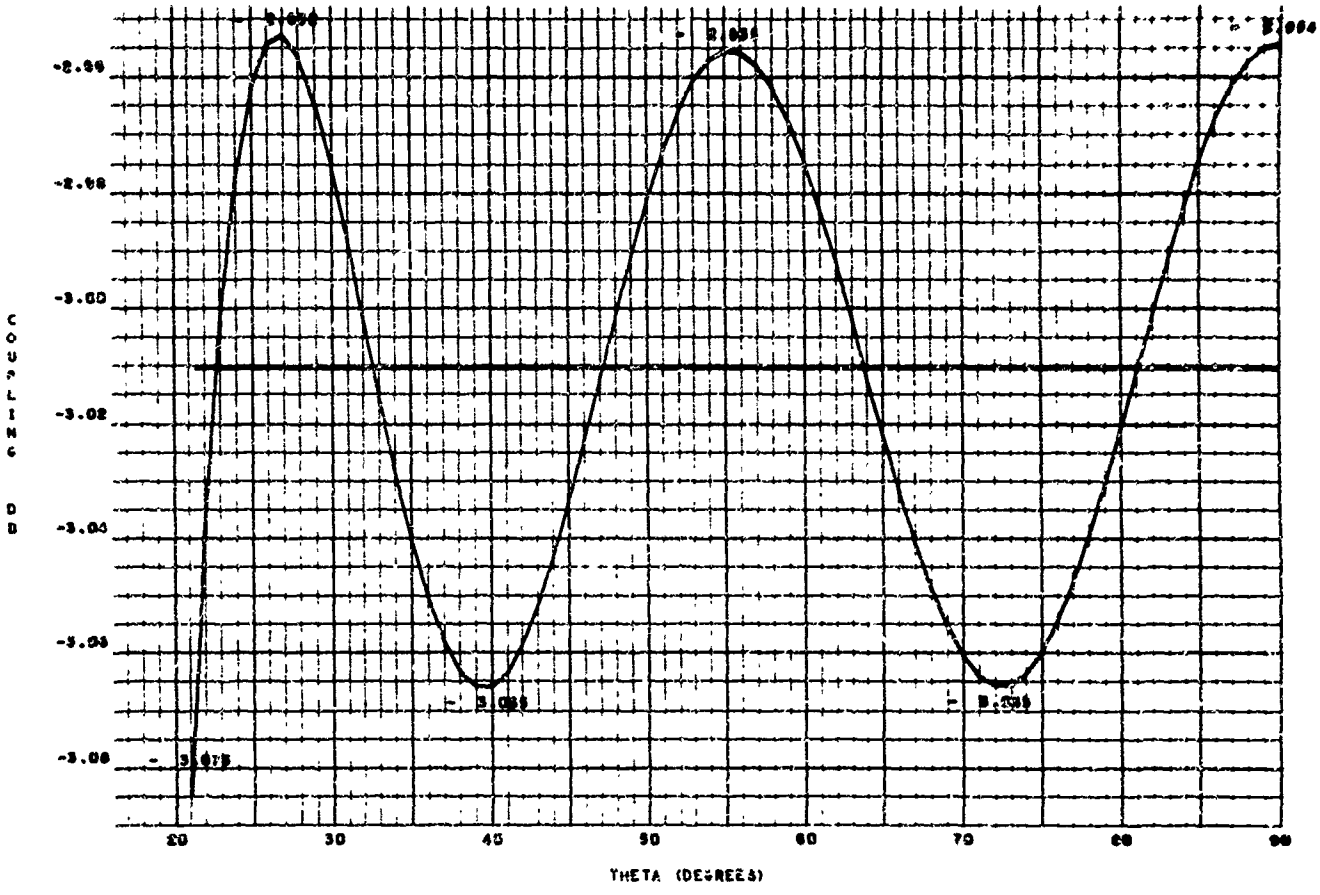


FIG. 16. Input Data Cards.



7.500 TO 1.0 BANDWIDTH COUPLER

4.50000 1.69714 1.25700 1.09536 1.02761
0.90588 3.48457 0.28462 0.09083 0.02748

1.69712
0.00034

FIG. 17. Response and Design of Coupler.

```
UO = 45.0000    BW = 7.500    ZMAX = 4.50000    TOLERANCE= 0.01000    THE MAX. ALLOWABLE ITERATION(S) ARE = 3
   4.93133    1.66958    1.24706    1.09163    1.02680
      GAMMA( 1, 1 ) =  0.49414
      GAMMA( 1, 2 ) =  0.14487
      GAMMA( 1, 3 ) =  0.06646
      GAMMA( 1, 4 ) =  0.03060
      GAMMA( 1, 5 ) =  0.01322
Z( 1, 1 )= 4.50000          GAMMA ( 1, 1 )=.45877          COUPLING = 0.90588
Z( 1, 2 )= 1.66958          GAMMA ( 1, 2 )=.14487          COUPLING = 0.47195
Z( 1, 3 )= 1.24706          GAMMA ( 1, 3 )=.06646          COUPLING = 0.21727
Z( 1, 4 )= 1.09163          GAMMA ( 1, 4 )=.03060          COUPLING = 0.08745
Z( 1, 5 )= 1.02680          GAMMA ( 1, 5 )=.01322          COUPLING = 0.02644
Z( 2, 1 )= 1.07333          GAMMA ( 2, 1 )=.03537          COUPLING = 0.07064

   ALPHA      RIPPLE      THETA     COUPLING    RIPPLE     BANDWIDTH
(DEGREES)  (DEGREES)  (DEGREES)     (DB)        (DB)       RATIO

 44.10265   0.89735    21.176    -3.14849    0.13819    7.50000
  9.82773  37.17227     2.000   -17.31677   14.30647   89.00000
 11.59411  33.40389     3.000   -13.93558   10.92528   59.00000
 15.70140  29.79860     4.000   -11.62692    8.61662   44.00000
 18.60626  26.39374     5.000    -9.92247    6.91217   35.00000
 21.78443  23.21557     6.000    -8.60982    5.59952   29.00000
 24.72024  20.27976     7.000    -7.57257    4.56227   24.71429
 27.40728  17.59272     8.000    -6.73894    3.72864   21.50000
 29.84660  15.15340     9.000    -6.06100    3.05070   19.00000
 32.04479  12.95521    10.000    -5.50495    2.49465   17.00000
 34.01232  10.98768    11.000    -5.04500    2.03570   15.36364
 35.76205   9.23795    12.000    -4.66549    1.65519   14.00000
 37.30818   7.69182    13.000    -4.34909    1.33879   12.84615
 38.66538   6.33462    14.000    -4.08558    1.07528   11.85714
 39.84629   5.15171    15.000    -3.86613    0.85583   11.00000
 40.87114   4.12886    16.000    -3.68367    0.67337   10.25000
 41.74760   3.25240    17.000    -3.53247    0.52217    9.58824
 42.49065   2.50935    18.000    -3.40788    0.39758    9.00000
 43.11258   1.88742    19.000    -3.30607    0.29577    8.47368
 43.62502   1.37498    20.000    -3.22383    0.21353    8.00000
 44.03901   0.96099    21.000    -3.15845    0.14815    7.57143
 44.36505   0.63495    22.000    -3.10763    0.09733    7.18182
 44.61314   0.38686    23.000    -3.06934    0.05904    6.82609
 44.79288   0.20712    24.000    -3.04181    0.03151    6.50000
 44.91348   0.08652    25.000    -3.02344    0.01314    6.20000
 44.98376   0.01624    26.000    -3.01276    0.00246    5.92308
 45.01222  -0.01222    27.000    -3.00845   -0.00185    5.66667
 45.00694  -0.00694    28.000    -3.00925   -0.00105    5.42857
 44.97560   0.02440    29.000    -3.01400    0.00370    5.20690
 44.92543   0.07457    30.000    -3.02162    0.01132    5.00000
 44.86311   0.13689    31.000    -3.03110    0.02080    4.80645
 44.79475   0.20525    32.000    -3.04153    0.03123    4.62500
 44.72580   0.27420    33.000    -3.05207    0.04177    4.45455
 44.66097   0.33903    34.000    -3.06200    0.05170    4.29412
 44.60426   0.39574    35.000    -3.07071    0.06041    4.14286
 44.55881   0.44119    36.000    -3.07770    0.06740    4.00000
 44.52696   0.47304    37.000    -3.08261    0.07231    3.86486
 44.51025   0.48975    38.000    -3.08518    0.07488    3.73684
 44.50940   0.49060    39.000    -3.08531    0.07501    3.61538
 44.52438   0.47562    40.000    -3.08300    0.07270    3.50000
 44.55453   0.44547    41.000    -3.07836    0.06806    3.39024
 44.59855   0.40145    42.000    -3.07159    0.06129    3.28571
 44.65465   0.34535    43.000    -3.06297    0.05267    3.18605
```

FIG. 18. "Written" Machine Output.

```
 44.72065   0.27935   44.000  -3.05786   0.04256   3.09091
 44.79409   0.20591   45.000  -3.04163   0.03133   3.00000
 44.87232   0.12768   46.000  -3.02970   0.01940   2.91304
 44.95264   0.04736   47.000  -3.01749   0.00719   2.82979
 45.03237  -0.03237   48.000  -3.00540  -0.00490   2.75000
 45.10897  -0.10897   49.000  -2.99381  -0.01649   2.67347
 45.18008  -0.18008   50.000  -2.98309  -0.02721   2.60000
 45.24363  -0.24363   51.000  -2.97352  -0.03678   2.52941
 45.29786  -0.29786   52.000  -2.96538  -0.04492   2.46154
 45.34138  -0.34138   53.000  -2.95885  -0.05145   2.39623
 45.37321  -0.37321   54.000  -2.95409  -0.05621   2.33333
 45.39274  -0.39274   55.000  -2.95117  -0.05913   2.27273
 45.39982  -0.39982   56.000  -2.95011  -0.06019   2.21429
 45.39468  -0.39468   57.000  -2.95088  -0.05942   2.15789
 45.37793  -0.37793   58.000  -2.95338  -0.05692   2.10345
 45.35057  -0.35057   59.000  -2.95748  -0.05282   2.05085
 45.31391  -0.31391   60.000  -2.96297  -0.04733   2.00000
 45.26953  -0.26953   61.000  -2.56963  -0.04067   1.95082
 45.21924  -0.21924   62.000  -2.97719  -0.03311   1.90323
 45.16503  -0.16503   63.000  -2.98535  -0.02495   1.85714
 45.10898  -0.10898   64.000  -2.99381  -0.01649   1.81250
 45.05322  -0.05322   65.000  -3.00224  -0.00806   1.76923
 44.99984   0.00016   66.000  -3.01032   0.00002   1.72727
 44.95084   0.04916   67.000  -3.01776   0.00746   1.68657
 44.90804   0.09196   68.000  -3.02426   0.01396   1.64706
 44.87307   0.12693   69.000  -3.02959   0.01929   1.60870
 44.84725   0.15275   70.000  -3.03352   0.02322   1.57143
 44.83160   0.16840   71.000  -3.03590   0.02560   1.53521
 44.82679   0.17321   72.000  -3.03664   0.02634   1.50000
 44.83312   0.16688   73.000  -3.03567   0.02537   1.46575
 44.85050   0.14950   74.000  -3.03302   0.02272   1.43243
 44.87848   0.12152   75.000  -3.02876   0.01846   1.40000
 44.91626   0.08374   76.000  -3.02301   0.01271   1.36842
 44.96271   0.03729   77.000  -3.01596   0.00566   1.33766
 45.01642  -0.01642   78.000  -3.00781  -0.00249   1.30769
 45.07574  -0.07574   79.000  -2.99883  -0.01147   1.27848
 45.13888  -0.13888   80.000  -2.98930  -0.02100   1.25000
 45.20390  -0.20390   81.000  -2.97950  -0.03080   1.22222
 45.26882  -0.26882   82.000  -2.96974  -0.04056   1.19512
 45.33167  -0.33167   83.000  -2.96031  -0.04999   1.16867
 45.39055  -0.39055   84.000  -2.95150  -0.05880   1.14286
 45.44369  -0.44369   85.000  -2.94356  -0.06674   1.11765
 45.48951  -0.48951   86.000  -2.93672  -0.07358   1.09302
 45.52663  -0.52663   87.000  -2.93119  -0.07911   1.06897
 45.55396  -0.55396   88.000  -2.92713  -0.08317   1.04545
 45.57069  -0.57069   89.000  -2.92464  -0.08566   1.02247
 45.57632  -0.57632   90.000  -2.92380  -0.08650   1.00000
VAL( 1)=   44.10265
VAL( 2)=   44.50940
VAL( 3)=   44.82679
PEAK( 1) =   45.01222
PEAK( 2) =   45.39982
PEAK( 3) =   45.57632
  0.13819   0.06468
  0.00185   0.06468
  0.07501   0.06468
  0.06019   0.06468
  0.02834   0.06468
  0.06650   0.06468
B( 1 )=-0.02196
B( 3 )= 0.28169
B( 5 )= 0.12511
B( 7 )= 0.04376
B( 9 )= 0.01792
B(11 )=-0.06792
0 1
```

FIG. 18. (Continued)

0 0

CAUTIOUS ERROR CORRECTION (0.750X)

GAMMA(1, 1) = 0.49399
GAMMA(1, 2) = 0.14671
GAMMA(1, 3) = 0.06728
GAMMA(1, 4) = 0.03089
GAMMA(1, 5) = 0.01334

Z(1, 1)= 4.50000
Z(1, 2)= 1.48000
Z(1, 3)= 1.25012
Z(1, 4)= 1.09251
Z(1, 5)= 1.02704
Z(2, 1)= 1.07831

GAMMA (1, 1)=.45631 COUPLING = 0.90588
GAMMA (1, 2)=.14671 COUPLING = 0.47877
GAMMA (1, 3)=.06728 COUPLING = 0.21961
GAMMA (1, 4)=.03089 COUPLING = 0.08825
GAMMA (1, 5)=.01334 COUPLING = 0.02668
GAMMA (2, 1)=.03768 COUPLING = 0.07526

ALPHA (DEGREES)	RIPPLE (DEGREES)	THETA (DEGREES)	COUPLING (DB)	RIPPLE (DB)	BANDWIDTH RATIO
44.29152	0.70848	21.176	-3.11904	0.10874	7.50000
7.87846	37.12154	2.000	-17.26101	14.25071	89.00000
11.47032	33.32968	3.000	-13.88094	10.97064	59.00000
15.29704	29.70296	4.000	-11.57374	8.58344	44.00000
18.72097	26.27903	5.000	-9.87099	6.86069	35.00000
21.91570	23.08430	6.000	-8.56019	5.54989	29.00000
24.86561	20.13439	7.000	-7.52486	4.51456	24.71429
27.56442	17.43558	8.000	-6.69315	3.68285	21.50000
30.01339	14.98661	9.000	-6.01708	3.00678	19.00000
32.21938	12.78062	10.000	-5.46281	2.45251	17.00000
34.19309	10.80691	11.000	-5.00553	1.99523	15.36364
35.94762	9.05238	12.000	-4.62657	1.61627	14.00000
37.49735	7.50265	13.000	-4.31158	1.30128	12.84615
38.85714	6.14286	14.000	-4.04938	1.03908	11.85714
40.04174	4.95826	15.000	-3.83111	0.82081	11.00000
41.06552	3.93448	16.000	-3.64973	0.63943	10.25000
41.94220	3.05780	17.000	-3.49952	0.48922	9.58824
42.68481	2.31519	18.000	-3.37586	0.36556	9.00000
43.30570	1.69430	19.000	-3.27490	0.26460	8.47368
43.81652	1.18348	20.000	-3.19347	0.18317	8.00000
44.22832	0.77168	21.000	-3.12887	0.11857	7.57143
44.55161	0.44839	22.000	-3.07881	0.06851	7.18182
44.79641	0.20359	23.000	-3.04127	0.03097	6.82609
44.97231	0.02769	24.000	-3.01450	0.00420	6.50000
45.08854	-0.08854	25.000	-2.99690	-0.01340	6.20000
45.15394	-0.15394	26.000	-2.98703	-0.02327	5.92308
45.17701	-0.17701	27.000	-2.98355	-0.02675	5.66667
45.16587	-0.16587	28.000	-2.98523	-0.02507	5.42857
45.12823	-0.12823	29.000	-2.99090	-0.01940	5.20690
45.07136	-0.07136	30.000	-2.99950	-0.01080	5.00000
45.00199	-0.00199	31.000	-3.01000	-0.00030	4.80645
44.92628	0.07372	32.000	-3.02149	0.01119	4.62500
44.84973	0.15027	33.000	-3.03314	0.02284	4.45455
44.77715	0.22285	34.000	-3.04422	0.03392	4.29412
44.71255	0.28745	35.000	-3.05410	0.04380	4.14286
44.65917	0.34083	36.000	-3.06226	0.05198	4.00000
44.61939	0.38061	37.000	-3.06838	0.05808	3.86486
44.59481	0.40519	38.000	-3.07216	0.06186	3.73684
44.58621	0.41379	39.000	-3.07349	0.06319	3.61538
44.59360	0.40640	40.000	-3.07235	0.06205	3.50000
44.61633	0.38367	41.000	-3.06885	0.05855	3.39024
44.65314	0.34686	42.000	-3.06320	0.05290	3.28571
44.70226	0.29774	43.000	-3.05567	0.04537	3.18605
44.76151	0.23849	44.000	-3.04661	0.03631	3.09091
44.82842	0.17158	45.000	-3.03639	0.02609	3.00000

FIG. 18. (Continued)

```
 44.90035   0.09965   46.000  -3.02543   0.01513   2.91304
 44.97457   0.02543   47.000  -3.01416   0.00386   2.82979
 45.04840  -0.04840   48.000  -3.00297  -0.00733   2.75000
 45.11924  -0.11924   49.000  -2.99226  -0.01804   2.67347
 45.18474  -0.18474   50.000  -2.98238  -0.02792   2.60000
 45.24279  -0.24279   51.000  -2.97365  -0.03665   2.52941
 45.29160  -0.29160   52.000  -2.96632  -0.04398   2.46154
 45.32977  -0.32977   53.000  -2.96059  -0.04971   2.39623
 45.35628  -0.35628   54.000  -2.95662  -0.05368   2.33333
 45.37054  -0.37054   55.000  -2.95449  -0.05581   2.27273
 45.37236  -0.37236   56.000  -2.95422  -0.05608   2.21429
 45.36197  -0.36197   57.000  -2.95577  -0.05453   2.15789
 45.34000  -0.34000   58.000  -2.95906  -0.05124   2.10345
 45.30743  -0.30743   59.000  -2.96394  -0.04636   2.05085
 45.26558  -0.26558   60.000  -2.97022  -0.04008   2.00000
 45.21607  -0.21607   61.000  -2.97767  -0.03263   1.95082
 45.16073  -0.16073   62.000  -2.98600  -0.02430   1.90323
 45.10156  -0.10156   63.000  -2.99493  -0.01537   1.85714
 45.04068  -0.04068   64.000  -3.00414  -0.00616   1.81250
 44.98024   0.01976   65.000  -3.01330   0.00300   1.76923
 44.92238   0.07762   66.000  -3.02208   0.01178   1.72727
 44.86911   0.13089   67.000  -3.03019   0.01989   1.68657
 44.82231   0.17769   68.000  -3.03732   0.02702   1.64706
 44.78360   0.21640   69.000  -3.04323   0.03293   1.60870
 44.75436   0.24564   70.000  -3.04770   0.03740   1.57143
 44.73561   0.26439   71.000  -3.05057   0.04027   1.53521
 44.72804   0.27196   72.000  -3.05173   0.04143   1.50000
 44.73194   0.26806   73.000  -3.05113   0.04083   1.46575
 44.74724   0.25276   74.000  -3.04879   0.03849   1.43243
 44.77348   0.22652   75.000  -3.04478   0.03448   1.40000
 44.80984   0.19016   76.000  -3.03922   0.02892   1.36842
 44.85517   0.14483   77.000  -3.03231   0.02201   1.33766
 44.90805   0.09193   78.000  -3.02426   0.01396   1.30769
 44.96679   0.03321   79.000  -3.01534   0.00504   1.27848
 45.02956  -0.02956   80.000  -3.00582  -0.00448   1.25000
 45.09440  -0.09440   81.000  -2.99601  -0.01429   1.22222
 45.15927  -0.15927   82.000  -2.98622  -0.02408   1.19512
 45.22219  -0.22219   83.000  -2.97675  -0.03355   1.16867
 45.28122  -0.28122   84.000  -2.96786  -0.04242   1.14286
 45.33654  -0.33454   85.000  -2.95988  -0.05042   1.11765
 45.38056  -0.38056   86.000  -2.95299  -0.05731   1.09302
 45.41786  -0.41786   87.000  -2.94741  -0.06289   1.06897
 45.44533  -0.44533   88.000  -2.94331  -0.06699   1.04545
 45.46216  -0.46216   89.000  -2.94080  -0.06950   1.02247
 45.46782  -0.46782   90.000  -2.93996  -0.07034   1.00000
VAL( 1)=   44.29152
VAL( 2)=   44.58671
VAL( 3)=   44.72804
PEAK( 1) =   45.17761
PEAK( 2) =   45.37236
PEAK( 3) =   45.46782
  0.10874   0.06109
  0.02675   0.06109
  0.06319   0.06109
  0.05858   0.06109
  0.04143   0.06109
  0.07034   0.06109
B( 2 )=-0.00327
B( 3 )= 0.25447
B( 5 )= 0.06174
B( 7 )= 0.04126
B( 9 )= 0.01684
B(11 )=-0.00364
0 1
3 0
     NORMAL ERROR CORRECTION
```

FIG. 18. (Continued)

```
      GAMMA( 1, 1 ) =  0.49395
      GAMMA( 1, 2 ) =  0.14873
      GAMMA( 1, 3 ) =  0.06835
      GAMMA( 1, 4 ) =  0.03143
      GAMMA( 1, 5 ) =  0.01356
   Z( 1, 1 )= 4.50000        GAMMA ( 1, 1 )=.45322        COUPLING = 0.90588
   Z( 1, 2 )= 1.69316        GAMMA ( 1, 2 )=.14873        COUPLING = 0.48278
   Z( 1, 3 )= 1.25472        GAMMA ( 1, 3 )=.06835        COUPLING = 0.22310
   Z( 1, 4 )= 1.09418        GAMMA ( 1, 4 )=.03143        COUPLING = 0.08976
   Z( 1, 5 )= 1.02749        GAMMA ( 1, 5 )=.01356        COUPLING = 0.02712
   Z( 2, 1 )= 1.08493        GAMMA ( 2, 1 )=.04073        COUPLING = 0.08133
```

ALPHA (DEGREES)	RIPPLE (DEGREES)	THETA (DEGREES)	COUPLING (DB)	RIPPLE (DB)	BANDWIDTH RATIO
44.51956	0.48044	21.176	-3.08275	0.07345	7.50000
7.94770	37.05230	2.000	-17.10549	14.17519	89.00000
11.77142	33.22858	3.000	-13.80707	10.74677	59.00000
15.42704	29.57296	4.000	-11.50200	8.49170	44.00000
18.87643	26.12357	5.000	-9.80176	6.79146	35.00000
22.09300	22.90700	6.000	-8.49368	5.48338	29.00000
25.06115	19.93885	7.000	-7.46118	4.45088	24.71429
27.77484	17.22516	8.000	-6.63232	3.62202	21.50000
30.23563	14.76437	9.000	-5.95902	2.94872	19.00000
32.45073	12.54927	10.000	-5.40740	2.39710	17.00000
34.43122	10.56878	11.000	-4.95263	1.94233	15.36364
36.19051	8.80949	12.000	-4.57601	1.56571	14.00000
37.74329	7.25671	13.000	-4.26320	1.25290	12.84615
39.10463	5.89537	14.000	-4.00301	0.99271	11.85714
40.28952	4.71048	15.000	-3.78641	0.77631	11.00000
41.31244	3.68756	16.000	-3.60995	0.59985	10.25000
42.18726	2.81274	17.000	-3.45836	0.44826	9.58824
42.92709	2.07291	18.000	-3.33620	0.32590	9.00000
43.54435	1.45565	19.000	-3.23868	0.22838	8.47368
44.05074	0.94926	20.000	-3.15682	0.14652	8.00000
44.45735	0.54265	21.000	-3.09335	0.08305	7.57143
44.77473	0.22527	22.000	-3.04458	0.03428	7.18182
45.01294	-0.01294	23.000	-3.00834	-0.00196	6.82609
45.18159	-0.18159	24.000	-2.98286	-0.02744	6.50000
45.28996	-0.28996	25.000	-2.96656	-0.04374	6.20000
45.34694	-0.34694	26.000	-2.95807	-0.05228	5.92308
45.36109	-0.36109	27.000	-2.95590	-0.05440	5.66667
45.34060	-0.34060	28.000	-2.95897	-0.05133	5.42857
45.29327	-0.29327	29.000	-2.96607	-0.04423	5.20690
45.22642	-0.22642	30.000	-2.97611	-0.03419	5.00000
45.14685	-0.14689	31.000	-2.98809	-0.02221	4.80645
45.06095	-0.06095	32.000	-3.00187	-0.00923	4.62500
44.97420	0.02580	33.000	-3.01421	0.00391	4.45455
44.89153	0.10847	34.000	-3.02678	0.01647	4.29412
44.81706	0.18294	35.000	-3.03812	0.02782	4.14286
44.75409	0.24591	36.000	-3.04774	0.03744	4.00000
44.70511	0.29489	37.000	-3.05523	0.04493	3.86486
44.67176	0.32824	38.000	-3.06035	0.05005	3.73684
44.65485	0.34515	39.000	-3.06294	0.05264	3.61538
44.65445	0.34555	40.000	-3.06300	0.05270	3.50000
44.66992	0.33008	41.000	-3.06063	0.05033	3.39024
44.69999	0.30001	42.000	-3.05602	0.04572	3.28571
44.74286	0.25714	43.000	-3.04946	0.03916	3.18605
44.79634	0.20366	44.000	-3.04128	0.03098	3.09091
44.85791	0.14209	45.000	-3.03189	0.02159	3.00000

FIG. 18. (Continued)

```
 44.92487   0.07513   46.000  -3.02170   0.01140   2.91304
 44.99445   0.00555   47.000  -3.01114   0.00084   2.82979
 45.06388  -0.06388   48.000  -3.00061  -0.00967   2.75000
 45.13054  -0.13054   49.000  -2.99056  -0.01974   2.67347
 45.19196  -0.19196   50.000  -2.98130  -0.02900   2.60000
 45.24601  -0.24601   51.000  -2.97317  -0.03713   2.52941
 45.29084  -0.29084   52.000  -2.96643  -0.04387   2.46154
 45.32497  -0.32497   53.000  -2.96131  -0.04899   2.39623
 45.34738  -0.34738   54.000  -2.95796  -0.05234   2.33333
 45.35742  -0.35742   55.000  -2.95645  -0.05385   2.27273
 45.35487  -0.35487   56.000  -2.95683  -0.05347   2.21429
 45.33997  -0.33997   57.000  -2.95907  -0.05123   2.15789
 45.31332  -0.31332   58.000  -2.96306  -0.04724   2.10345
 45.27593  -0.27593   59.000  -2.96867  -0.04163   2.05085
 45.22914  -0.22914   60.000  -2.97570  -0.03460   2.00000
 45.17456  -0.17456   61.000  -2.98392  -0.02638   1.95082
 45.11408  -0.11408   62.000  -2.99304  -0.01726   1.90323
 45.04975  -0.04975   63.000  -3.00277  -0.00754   1.85714
 44.98371   0.01629   64.000  -3.01277   0.00247   1.81250
 44.91819   0.08181   65.000  -3.02272   0.01242   1.76923
 44.85535   0.14465   66.000  -3.03228   0.02198   1.72727
 44.79728   0.20272   67.000  -3.04114   0.03084   1.68657
 44.74590   0.25410   68.000  -3.04899   0.03869   1.64706
 44.70288   0.29712   69.000  -3.05558   0.04528   1.60870
 44.66964   0.33036   70.000  -3.06067   0.05037   1.57143
 44.64723   0.35277   71.000  -3.06411   0.05381   1.53521
 44.63639   0.36361   72.000  -3.06577   0.05547   1.50000
 44.63741   0.36259   73.000  -3.06562   0.05532   1.46575
 44.65025   0.34975   74.000  -3.06365   0.05335   1.43243
 44.67442   0.32558   75.000  -3.05994   0.04964   1.40000
 44.70911   0.29089   76.000  -3.05462   0.04432   1.36842
 44.75315   0.24685   77.000  -3.04788   0.03758   1.33766
 44.80508   0.19492   78.000  -3.03995   0.02965   1.30769
 44.86320   0.13680   79.000  -3.03109   0.02079   1.27848
 44.92561   0.07439   80.000  -3.02159   0.01129   1.25000
 44.99032   0.00968   81.000  -3.01177   0.00147   1.22222
 45.05525  -0.05525   82.000  -3.00193  -0.00837   1.19512
 45.11835  -0.11835   83.000  -2.99240  -0.01791   1.16867
 45.17765  -0.17765   84.000  -2.98345  -0.02685   1.14286
 45.23130  -0.23130   85.000  -2.97538  -0.03492   1.11765
 45.27763  -0.27763   86.000  -2.96842  -0.04188   1.09302
 45.31521  -0.31521   87.000  -2.96278  -0.04752   1.06897
 45.34291  -0.34291   88.000  -2.95863  -0.05168   1.04545
 45.35988  -0.35988   89.000  -2.95608  -0.05422   1.02247
 45.36559  -0.36559   90.000  -2.95523  -0.05507   1.00000
VAL( 1)=   44.31956
VAL( 2)=   44.65445
VAL( 3)=   44.63639
PEAK( 1) =   45.36109
PEAK( 2) =   45.35742
PEAK( 3) =   45.36559
  0.07345   0.05749
  0.05440   0.05749
  0.05270   0.05749
  0.05385   0.05749
  0.05547   0.05749
  0.05507   0.05749
B( 1 )= 0.00478
B( 3 )= 0.01472
B( 5 )= 0.02798
B( 7 )= 0.02729
B( 9 )= 0.01400
B(11 )=-0.01438
0 1
0 0
     NORMAL ERROR CORRECTION
```

FIG. 18. (Continued)

```
      GAMMA( 1, 1 ) =  0.49403
      GAMMA( 1, 2 ) =  0.14899
      GAMMA( 1, 3 ) =  0.06872
      GAMMA( 1, 4 ) =  0.03179
      GAMMA( 1, 5 ) =  0.01374
Z( 1, 1 )= 4.50000        GAMMA ( 1, 1 )=.45228        COUPLING = 0.90588
Z( 1, 2 )= 1.65714        GAMMA ( 1, 2 )=.14899        COUPLING = 0.48457
Z( 1, 3 )= 1.25700        GAMMA ( 1, 3 )=.06872        COUPLING = 0.22482
Z( 1, 4 )= 1.09536        GAMMA ( 1, 4 )=.03179        COUPLING = 0.09083
Z( 1, 5 )= 1.02787        GAMMA ( 1, 5 )=.01374        COUPLING = 0.02748
Z( 2, 1 )= 1.08712        GAMMA ( 2, 1 )=.04174        COUPLING = 0.08334
```

ALPHA (DEGREES)	RIPPLE (DEGREES)	THETA (DEGREES)	COUPLING (DB)	RIPPLE (DB)	BANDWIDTH RATIO
44.57127	0.42873	21.176	-3.07578	0.04548	7.50000
7.97502	37.02498	2.000	-17.15589	14.14559	89.00000
11.81109	33.18891	3.000	-13.77826	10.76796	59.00000
15.47768	29.52232	4.000	-11.47423	8.46393	44.00000
18.93643	26.06357	5.000	-9.77520	6.76490	35.00000
22.16064	22.83936	6.000	-8.46846	5.45816	29.00000
25.13476	19.86524	7.000	-7.43736	4.42706	24.71429
27.85282	17.14718	8.000	-6.60991	3.59961	21.50000
30.31654	14.68346	9.000	-5.93801	2.92771	19.00000
32.53330	12.46670	10.000	-5.38775	2.37745	17.00000
34.51439	10.48567	11.000	-4.93428	1.92398	15.36364
36.27320	8.72680	12.000	-4.55891	1.54861	14.00000
37.82474	7.17526	13.000	-4.24727	1.23697	12.84615
39.18415	5.81585	14.000	-3.98820	0.97790	11.85714
40.36648	4.63352	15.000	-3.77287	0.76257	11.00000
41.38633	3.61367	16.000	-3.59423	0.58393	10.25000
42.25760	2.74240	17.000	-3.44661	0.43631	9.58824
42.99349	2.00651	18.000	-3.32539	0.31509	9.00000
43.60645	1.39355	19.000	-3.22678	0.21648	8.47368
44.10822	0.89178	20.000	-3.14762	0.13732	8.00000
44.50955	0.49005	21.000	-3.08523	0.07493	7.57143
44.82222	0.17778	22.000	-3.03733	0.02703	7.18182
45.05513	-0.05513	23.000	-3.00195	-0.00835	6.82609
45.21837	-0.21837	24.000	-2.97732	-0.03298	6.50000
45.32124	-0.32124	25.000	-2.96187	-0.04843	6.20000
45.37271	-0.37271	26.000	-2.95416	-0.05614	5.92308
45.38140	-0.38140	27.000	-2.95286	-0.05744	5.66667
45.35557	-0.35557	28.000	-2.95673	-0.05357	5.42847
45.30306	-0.30306	29.000	-2.96460	-0.04570	5.20690
45.23131	-0.23131	30.000	-2.97537	-0.03493	5.00000
45.14721	-0.14721	31.000	-2.98804	-0.02226	4.80645
45.05707	-0.05707	32.000	-3.00166	-0.00864	4.62500
44.96658	0.03342	33.000	-3.01537	0.00507	4.45455
44.88065	0.11935	34.000	-3.02843	0.01813	4.29412
44.80346	0.19654	35.000	-3.04020	0.02990	4.14286
44.73634	0.26366	36.000	-3.05013	0.03983	4.00000
44.68777	0.31223	37.000	-3.05709	0.04679	3.86486
44.65340	0.34660	38.000	-3.06316	0.05286	3.73684
44.63604	0.36396	39.000	-3.06583	0.05553	3.61538
44.63571	0.36429	40.000	-3.06588	0.05558	3.50000
44.65174	0.34826	41.000	-3.06342	0.05312	3.39024
44.68281	0.31719	42.000	-3.05865	0.04835	3.28571
44.72706	0.27294	43.000	-3.05187	0.04157	3.18605
44.78223	0.21777	44.000	-3.04344	0.03314	3.09091
44.84575	0.15425	45.000	-3.03375	0.02345	3.00000

FIG. 18. (Continued)

```
44.91485   0.08515    46.000   -3.02323    0.01293    2.91304
44.98666   0.01334    47.000   -3.01232    0.00202    2.82979
45.05837  -0.05837    48.000   -3.00146   -0.00884    2.75000
45.12728  -0.12728    49.000   -2.99105   -0.01925    2.67347
45.19090  -0.19090    50.000   -2.98146   -0.02884    2.60000
45.24700  -0.24700    51.000   -2.97302   -0.03728    2.52941
45.29371  -0.29371    52.000   -2.96600   -0.04430    2.46154
45.32953  -0.32953    53.000   -2.96063   -0.04967    2.39623
45.35337  -0.35337    54.000   -2.95706   -0.05324    2.33333
45.36460  -0.36460    55.000   -2.95538   -0.05492    2.27273
45.36297  -0.36297    56.000   -2.95562   -0.05468    2.21429
45.34872  -0.34872    57.000   -2.95776   -0.05254    2.15789
45.32245  -0.32245    58.000   -2.96169   -0.04861    2.10345
45.28519  -0.28519    59.000   -2.96728   -0.04302    2.05085
45.23828  -0.23828    60.000   -2.97433   -0.03597    2.00000
45.18338  -0.18338    61.000   -2.98259   -0.02771    1.95082
45.12239  -0.12239    62.000   -2.99179   -0.01851    1.90323
45.05738  -0.05738    63.000   -3.00161   -0.00869    1.85714
44.99056   0.00944    64.000   -3.01173    0.00143    1.81250
44.92417   0.07583    65.000   -3.02181    0.01151    1.76923
44.86042   0.13958    66.000   -3.03151    0.02121    1.72727
44.80163   0.19837    67.000   -3.04051    0.03021    1.68657
44.74916   0.25084    68.000   -3.04849    0.03819    1.64706
44.70533   0.29467    69.000   -3.05520    0.04490    1.60870
44.67136   0.32864    70.000   -3.06041    0.05011    1.57143
44.64835   0.35165    71.000   -3.06394    0.05364    1.53521
44.63704   0.36296    72.000   -3.06567    0.05537    1.50000
44.63776   0.36224    73.000   -3.06556    0.05526    1.46575
44.65043   0.34957    74.000   -3.06362    0.05332    1.43243
44.67462   0.32538    75.000   -3.05991    0.04961    1.40000
44.70947   0.29053    76.000   -3.05457    0.04427    1.36842
44.75382   0.24618    77.000   -3.04778    0.03748    1.33766
44.80618   0.19382    78.000   -3.03978    0.02948    1.30769
44.86484   0.13516    79.000   -3.03084    0.02054    1.27848
44.92788   0.07212    80.000   -3.02125    0.01095    1.25000
44.99326   0.00674    81.000   -3.01132    0.00102    1.22222
45.05890  -0.05890    82.000   -3.00138   -0.00892    1.19512
45.12271  -0.12271    83.000   -2.99174   -0.01856    1.16867
45.18268  -0.18268    84.000   -2.98269   -0.02761    1.14286
45.23695  -0.23695    85.000   -2.97453   -0.03577    1.11765
45.28382  -0.28382    86.000   -2.96749   -0.04281    1.09302
45.32186  -0.32186    87.000   -2.96178   -0.04852    1.06897
45.34989  -0.34989    88.000   -2.95758   -0.05272    1.04545
45.36705  -0.36705    89.000   -2.95501   -0.05529    1.02247
45.37284  -0.37284    90.000   -2.95415   -0.05615    1.00000
VAL( 1)=   44.57127
VAL( 2)=   44.63571
VAL( 3)=   44.63704
PEAK( 1) =   45.38140
PEAK( 2) =   45.36460
PEAK( 3) =   45.37284
  0.06548   0.05749
  0.05744   0.05749
  0.05558   0.05749
  0.05492   0.05749
  0.05537   0.05749
  0.05615   0.05749
   THE DESIGN DOES NOT MEET THE SPECIFICATIONS -- FAIL
                                          EXIT BY 6
```

FIG. 18. End.

```
1 5 -0 3   1.30000   45.00000   0.01000   4.50000   7.50000
  0.49403   0.14899   0.06872   0.03179   0.01374
     FOR REFERENCE
1234567890123450 5 0 5 0 5 0 5 0 5 012
```

FIG. 19.

Example E
Type 4 Data

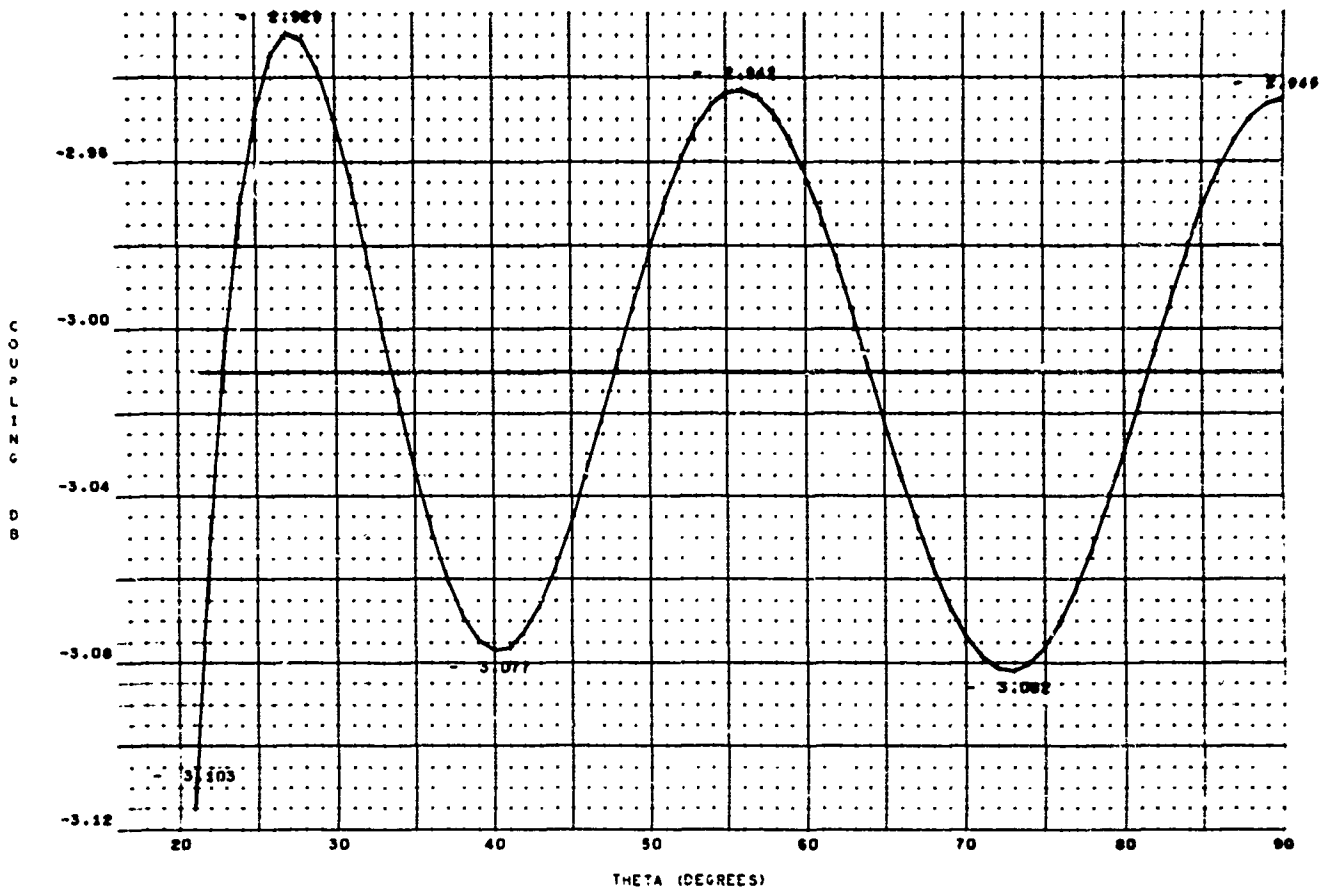
Should it be desired to calculate a coupler similar to the presently completed one of example D except for Zoe = 3.0, then one could take the output data of example D (Fig. 19) to be the input now. However, one can save the punching of Γ's, Zoe's, etc., by punching CONT = 5. on the first data card. This simply saves the design data from the previous design to be the new starting data. Thus, Fig. 20 was prepared as input and Fig. 21-23 are its output.

One should use the Type 4 data input with some discretion. One would not, for instance, start the design of a 5-section phase shifter based on a previously completed design of a 6-section phase shifter.[3] However, one can start a solution by using a presently completed solution of basically the same device except changes in Z max. and BW, or both. Obviously, the greater the differences between the known and the desired designs, the longer the iteration process and the less efficient the method of design.

The computer execution time was 3.72 seconds.

[3] It is interesting to note that in preparing the input data for example C above, an error in copying data was made resulting in a deletion of a coupled section of Zoe = 1.8343. Thus, the machine started the design of a 5-section phase shifter with the data from basically a 6-section coupler (see Fig. 24 for actual input data cards). To see how the machine performed under this input, see Fig. 25 where the performance response's maxima/minima (peaks/valleys) are listed (between θ = 0 degree to θ = 90 degrees), also see Fig. 26 for final response plot. Thus, the initial response does not have the "proper" number of maxima/minima, but after one iteration, this has been rectified. No complete analysis has been made to specify, in general, how poor a starting solution can be and still have the machine converge on a meaningful result.

FIG. 20. Input Data Cards.



7.500 TO 1.0 BANDWIDTH COUPLER

3.00000 1.71721 1.27373 1.10174 1.02930
0.80000 0.49351 0.23734 0.09658 0.02887

1.56851
0.42200

FIG. 21. Response Curve and Design Data of Coupler.

```
UG = 45.0000    BW = 7.500    ZMAX = 3.00000    TOLERANCE= 0.01000    THE MAX. ALLOWABLE ITERATION(S) ARE = 3
     GAMMA( 1, 1 ) =  0.49403
     GAMMA( 1, 2 ) =  0.14899
     GAMMA( 1, 3 ) =  0.06872
     GAMMA( 1, 4 ) =  0.03179
     GAMMA( 1, 5 ) =  0.01374
Z( 1, 1 )= 3.00000          GAMMA ( 1, 1 )=.27737          COUPLING = 0.80000
Z( 1, 2 )= 1.69714          GAMMA ( 1, 2 )=.14899          COUPLING = 0.48457
Z( 1, 3 )= 1.25700          GAMMA ( 1, 3 )=.06872          COUPLING = 0.22482
Z( 1, 4 )= 1.09536          GAMMA ( 1, 4 )=.03179          COUPLING = 0.09083
Z( 1, 5 )= 1.02787          GAMMA ( 1, 5 )=.01374          COUPLING = 0.02748
Z( 2, 1 )= 1.55315          GAMMA ( 2, 1 )=.21665          COUPLING = 0.41388
VAL( 1)=   44.03745
VAL( 2)=   44.98100
VAL( 3)=   45.50417
PEAK( 1) =   45.47265
PEAK( 2) =   45.76817
PEAK( 3) =   45.23376
  0.14840   0.07473
  0.07106   0.07473
  0.00288   0.07473
  0.11490   0.07473
  0.07582   0.07473
  0.03530   0.07473
B( 1 )=-0.10551
B( 3 )=-0.07071
B( 5 )= 0.30377
B( 7 )= 0.14159
B( 9 )= 0.02573
B(11 )=-0.07159
0 1
0 0
     CAUTIOUS ERROR CORRECTION ( 0.500X)
     GAMMA( 1, 1 ) =  0.49357
     GAMMA( 1, 2 ) =  0.14868
     GAMMA( 1, 3 ) =  0.07004
     GAMMA( 1, 4 ) =  0.03240
     GAMMA( 1, 5 ) =  0.01386
Z( 1, 1 )= 3.00000          GAMMA ( 1, 1 )=.27576          COUPLING = 0.80000
Z( 1, 2 )= 1.70308          GAMMA ( 1, 2 )=.14868          COUPLING = 0.48724
Z( 1, 3 )= 1.26220          GAMMA ( 1, 3 )=.07004          COUPLING = 0.22874
Z( 1, 4 )= 1.09696          GAMMA ( 1, 4 )=.03240          COUPLING = 0.09228
Z( 1, 5 )= 1.02810          GAMMA ( 1, 5 )=.01386          COUPLING = 0.02771
Z( 2, 1 )= 1.55691          GAMMA ( 2, 1 )=.21781          COUPLING = 0.41588
VAL( 1)=   44.14386
VAL( 2)=   44.83016
VAL( 3)=   44.50542
PEAK( 1) =   45.48783
PEAK( 2) =   45.61377
PEAK( 3) =   45.29504
  0.13175   0.07385
  0.07333   0.07385
  0.02582   0.07385
  0.09206   0.07385
  0.07563   0.07385
  0.04450   0.07385
B( 1 )=-0.04063
B( 3 )=-0.03794
B( 5 )= 0.20366
B( 7 )= 0.11312
B( 9 )= 0.02819
```

FIG. 22. "Written" Machine Output.

```
B(11 )=-0.05401
0 1
0 0
      NORMAL ERROR CORRECTION
     GAMMA(1, 1 ) =  0.49321
     GAMMA(1, 2 ) =  0.14835
     GAMMA(1, 3 ) =  0.07182
     GAMMA(1, 4 ) =  0.03339
     GAMMA(1, 5 ) =  0.01410
Z( 1, 1 )= 3.00000        GAMMA ( 1, 1 )=.27328        COUPLING = 0.80000
Z( 1, 2 )= 1.71224        GAMMA ( 1, 2 )=.14835        COUPLING = 0.49132
Z( 1, 3 )= 1.26985        GAMMA ( 1, 3 )=.07182        COUPLING = 0.23645
Z( 1, 4 )= 1.09467        GAMMA ( 1, 4 )=.03339        COUPLING = 0.09473
Z( 1, 5 )= 1.02861        GAMMA ( 1, 5 )=.01410        COUPLING = 0.02820
Z( 2, 1 )= 1.56388        GAMMA ( 2, 1 )=.21993        COUPLING = 0.41957
VAL( 1)=   44.31430
VAL( 2)=   44.63572
VAL( 3)=   44.52018
PEAK( 1) =   45.52400
PEAK( 2) =   45.45020
PEAK( 3) =   45.38812
  0.10520   0.07319
  0.07883   0.07319
  0.05558   0.07319
  0.06772   0.07319
  0.07335   0.07319
  0.05844   0.07319
B( 1 )= 0.00761
B( 3 )=-0.00929
B( 5 )= 0.06779
B( 7 )= 0.06859
B( 9 )= 0.03875
B(11 )=-0.02927
0 1
0 0
      NORMAL ERROR CORRECTION
     GAMMA(1, 1 ) =  0.49328
     GAMMA(1, 2 ) =  0.14827
     GAMMA(1, 3 ) =  0.07241
     GAMMA(1, 4 ) =  0.03399
     GAMMA(1, 5 ) =  0.01444
Z( 1, 1 )= 3.00000        GAMMA ( 1, 1 )=.27194        COUPLING = 0.80000
Z( 1, 2 )= 1.71721        GAMMA ( 1, 2 )=.14827        COUPLING = 0.49352
Z( 1, 3 )= 1.27375        GAMMA ( 1, 3 )=.07241        COUPLING = 0.23735
Z( 1, 4 )= 1.10174        GAMMA ( 1, 4 )=.03399        COUPLING = 0.09659
Z( 1, 5 )= 1.02930        GAMMA ( 1, 5 )=.01444        COUPLING = 0.02887
Z( 2, 1 )= 1.56851        GAMMA ( 2, 1 )=.22134        COUPLING = 0.42200
VAL( 1)=   44.39341
VAL( 2)=   44.56303
VAL( 3)=   44.53014
PEAK( 1) =   45.53736
PEAK( 2) =   45.44840
PEAK( 3) =   45.43114
  0.09294   0.07409
  0.08070   0.07409
  0.06675   0.07409
  0.06745   0.07409
  0.07182   0.07409
  0.06487   0.07409
   THE DESIGN DOES NOT MEET THE SPECIFICATIONS -- FAIL
                                        EXIT AV 6
Z(1, 1)    4.50000  3.00000
Z(1, 2)    1.69714  1.71721
Z(1, 3)    1.25700  1.27375
Z(1, 4)    1.09536  1.10174
Z(1, 5)    1.02787  1.02930
Z(2, 1)    1.08712  1.56851
```

FIG. 22. End.

```
 1 5 -0  3    1.00000    45.00000    0.01000    3.00000    7.50000
    0.49328    0.14827    0.07241    0.03399    0.01444
        FOR REFERENCE
1234567890123450 5 0 5 0 5 0 5 0 5 0 5 012
```

FIG. 23.

```
1.566

 1

1.83434     1.17
 0           0

 2

1.83434     1.83434   1.823
 0           0         0

 3

1.83434     1.83434   1.725      1.385      1.3
 0           0         0          0          0

 =

 1 4        1.00001
             0

   5    3   2.          90.         .03       1.83434   17.
            2            0           0         0         0
```

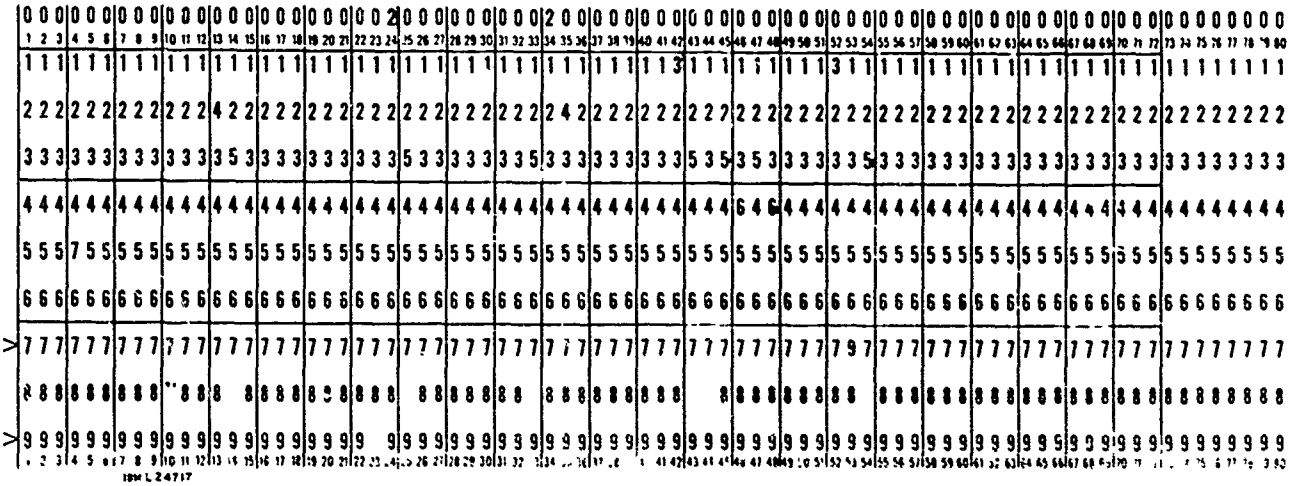


FIG. 24. Input Data Cards.

```
U0 = 90.0000    BW =17.000    ZMAX = 1.83434    TOLERANCE= 0.02000    THE MAX. ALLOWABLE ITERATION(S) ARE =  8
  1.83434   1.83434   1.72500   1.38500   1.20000
  1.83434   1.83434   1.22300
  1.83434   1.17000
  1.56600
    GAMMA( 1, 1 ) =  0.44170
    GAMMA( 1, 2 ) =  0.30902
    GAMMA( 1, 3 ) =  0.20964
    GAMMA( 1, 4 ) =  0.07157
    GAMMA( 1, 5 ) =  0.09091
Z( 1, 1 )= 1.83434        GAMMA ( 1, 1 )=.          COUPLING = 0.54179
Z( 1, 2 )= 1.83434        GAMMA ( 1, 2 )=.          COUPLING = 0.54179
Z( 1, 3 )= 1.83434        GAMMA ( 1, 3 )=.13958     COUPLING = 0.54179
Z( 1, 4 )= 1.38500        GAMMA ( 1, 4 )=.07157     COUPLING = 0.31465
Z( 1, 5 )= 1.20000        GAMMA ( 1, 5 )=.09091     COUPLING = 0.18033
Z( 2, 1 )= 1.83434        GAMMA ( 2, 1 )=.          COUPLING = 0.54179
Z( 2, 2 )= 1.83434        GAMMA ( 2, 2 )=.22903     COUPLING = 0.54179
Z( 2, 3 )= 1.15069        GAMMA ( 2, 3 )=.07006     COUPLING = 0.13944
Z( 3, 1 )= 1.83434        GAMMA ( 3, 1 )=.21955     COUPLING = 0.54179
Z( 3, 2 )= 1.17389        GAMMA ( 3, 2 )=.07999     COUPLING = 0.15896
Z( 4, 1 )= 1.57121        GAMMA ( 4, 1 )=.22216     COUPLING = 0.42362

VAL( 1)=   79.02715
VAL( 2)=   79.37369
PEAK( 1) =  108.53836
PEAK( 2) =  103.10774
 10.97285   8.87421
-18.53836   8.87421
 10.62631   8.87421
-13.10774   8.87421
B( 2 )=-3.64270
B( 4 )=-2.84412
B( 6 )=-1.62765
B( 8 )= 2.09687
B(10 )= 0.30100
B(12 )= 1.70949
0 2
0 0
    CAUTIOUS ERROR CORRECTION ( 0.500X)
    GAMMA( 1, 1 ) =  0.40991
    GAMMA( 1, 2 ) =  0.28420
    GAMMA( 1, 3 ) =  0.19544
    GAMMA( 1, 4 ) =  0.08987
    GAMMA( 1, 5 ) =  0.09354
Z( 1, 1 )= 1.83434        GAMMA ( 1, 1 )=.          COUPLING = 0.54179
Z( 1, 2 )= 1.83434        GAMMA ( 1, 2 )=.          COUPLING = 0.54179
Z( 1, 3 )= 1.83434        GAMMA ( 1, 3 )=.11886     COUPLING = 0.54179
Z( 1, 4 )= 1.44461        GAMMA ( 1, 4 )=.08987     COUPLING = 0.35210
Z( 1, 5 )= 1.20637        GAMMA ( 1, 5 )=.09354     COUPLING = 0.18545
Z( 2, 1 )= 1.83434        GAMMA ( 2, 1 )=.          COUPLING = 0.54179
Z( 2, 2 )= 1.83434        GAMMA ( 2, 2 )=.22281     COUPLING = 0.54179
Z( 2, 3 )= 1.16586        GAMMA ( 2, 3 )=.07658     COUPLING = 0.15226
Z( 3, 1 )= 1.83434        GAMMA ( 3, 1 )=.23727     COUPLING = 0.54179
Z( 3, 2 )= 1.13080        GAMMA ( 3, 2 )=.06139     COUPLING = 0.12231
Z( 4, 1 )= 1.41734        GAMMA ( 4, 1 )=.17264     COUPLING = 0.33530

VAL( 1)=   77.66069
VAL( 2)=   84.04846
VAL( 3)=   80.13509
PEAK( 1) =  104.45723
PEAK( 2) =   85.22576
```

FIG. 25

FIG. 25.

```
PEAK( 3) =   99.96368
 12.33931   9.55849
-14.45723   9.55849
  5.95154   9.55849
  4.77424   9.55849
  5.86491   9.55849
 -9.96368   9.55849
B( 2 )= 2.49336
B( 4 )=-1.94682
B( 6 )=-3.91717
B( 8 )= 1.50809
B(10 )= 3.73471
B(12 )= 0.53852
0 2
0 0
        NORMAL ERROR CORRECTION
     GAMMA( 1,  1 ) =  0.45343
     GAMMA( 1,  2 ) =  0.25022
     GAMMA( 1,  3 ) =  0.12707
     GAMMA( 1,  4 ) =  0.11619
     GAMMA( 1,  5 ) =  0.15872
Z( 1, 1 )= 1.83434        GAMMA ( 1, 1 )=.          COUPLING = 0.54179
Z( 1, 2 )= 1.83434        GAMMA ( 1, 2 )=.          COUPLING = 0.54179
Z( 1, 3 )= 1.83434        GAMMA ( 1, 3 )=.02655     COUPLING = 0.54179
Z( 1, 4 )= 1.73945        GAMMA ( 1, 4 )=.11619     COUPLING = 0.50319
Z( 1, 5 )= 1.37733        GAMMA ( 1, 5 )=.15872     COUPLING = 0.30964
Z( 2, 1 )= 1.83434        GAMMA ( 2, 1 )=.          COUPLING = 0.54179
Z( 2, 2 )= 1.83434        GAMMA ( 2, 2 )=.19976     COUPLING = 0.54179
Z( 2, 3 )= 1.22351        GAMMA ( 2, 3 )=.10052     COUPLING = 0.19903
Z( 3, 1 )= 1.83434        GAMMA ( 3, 1 )=.24759     COUPLING = 0.54179
Z( 3, 2 )= 1.10628        GAMMA ( 3, 2 )=.05046     COUPLING = 0.10066
Z( 4, 1 )= 1.51841        GAMMA ( 4, 1 )=.20585     COUPLING = 0.39496

VAL( 1)=   81.11431
VAL( 2)=   75.76743
VAL( 3)=   81.71696
PEAK( 1) =   99.63038
PEAK( 2) =  105.58012
PEAK( 3) =  102.53235
  8.88569  11.52402
 -9.63038  11.52402
 14.23257  11.52402
-15.58012  11.52402
  8.28304  11.52402
-12.53235  11.52402
B( 2 )=-1.81699
B( 4 )= 2.15918
B( 6 )= 0.50667
B( 8 )=-0.96798
B(10 )=-1.03985
B(12 )=-0.60214
0 2
0 0
        NORMAL ERROR CORRECTION
     GAMMA( 1,  1 ) =  0.42172
     GAMMA( 1,  2 ) =  0.28790
     GAMMA( 1,  3 ) =  0.13591
     GAMMA( 1,  4 ) =  0.09929
     GAMMA( 1,  5 ) =  0.14057
Z( 1, 1 )= 1.83434        GAMMA ( 1, 1 )=.          COUPLING = 0.54179
Z( 1, 2 )= 1.83434        GAMMA ( 1, 2 )=.          COUPLING = 0.54179
Z( 1, 3 )= 1.83434        GAMMA ( 1, 3 )=.06213     COUPLING = 0.54179
Z( 1, 4 )= 1.61972        GAMMA ( 1, 4 )=.09929     COUPLING = 0.44805
Z( 1, 5 )= 1.32712        GAMMA ( 1, 5 )=.14057     COUPLING = 0.27569
Z( 2, 1 )= 1.83434        GAMMA ( 2, 1 )=.          COUPLING = 0.54179
Z( 2, 2 )= 1.83434        GAMMA ( 2, 2 )=.22549     COUPLING = 0.54179
```

FIG. 25. (Continued)

```
Z( 2, 3 )= 1.15931          GAMMA ( 2, 3 )=.07378          C@UPLING = 0.14676
Z( 3, 1 )= 1.83434          GAMMA ( 3, 1 )=.23629          C@UPLING = 0.54179
Z( 3, 2 )= 1.13314          GAMMA ( 3, 2 )=.06242          C@UPLING = 0.12435
Z( 4, 1 )= 1.45527          GAMMA ( 4, 1 )=.18543          C@UPLING = 0.35853

VAL( 1)=   79.49659
VAL( 2)=   80.42321
VAL( 3)=   74.75529
PEAK( 1) =  100.30775
PEAK( 2) =   97.99684
PEAK( 3) =   93.39865
 10.50341  10.50469
-10.30775  10.50469
  9.57679  10.50469
 -7.99684  10.50469
 15.24471  10.50469
 -9.39865  10.50469
B( 2 )= 2.29813
B( 4 )=-2.09003
B( 6 )= 0.11327
B( 8 )= 0.55265
B(10 )=-0.01998
B(12 )= 0.17868
0 2
0 2
THE ERR@R C@EFFICIENT  2 IS @SCILLATING, APPLY FIX 1
    GAMMA(1, 1 ) =  0.44075
    GAMMA(1, 2 ) =  0.26529
    GAMMA(1, 3 ) =  0.13061
    GAMMA(1, 4 ) =  0.10943
    GAMMA(1, 5 ) =  0.15146
Z( 1, 1 )= 1.83434          GAMMA ( 1, 1 )=.            C@UPLING = 0.54179
Z( 1, 2 )= 1.83434          GAMMA ( 1, 2 )=.            C@UPLING = 0.54179
Z( 1, 3 )= 1.83434          GAMMA ( 1, 3 )=.04082       C@UPLING = 0.54179
Z( 1, 4 )= 1.69047          GAMMA ( 1, 4 )=.10943       C@UPLING = 0.48155
Z( 1, 5 )= 1.35699          GAMMA ( 1, 5 )=.15146       C@UPLING = 0.29613
Z( 2, 1 )= 1.83434          GAMMA ( 2, 1 )=.            C@UPLING = 0.54179
Z( 2, 2 )= 1.83434          GAMMA ( 2, 2 )=.21013       C@UPLING = 0.54179
Z( 2, 3 )= 1.19729          GAMMA ( 2, 3 )=.08979       C@UPLING = 0.17814
Z( 3, 1 )= 1.83434          GAMMA ( 3, 1 )=.24316       C@UPLING = 0.54179
Z( 3, 2 )= 1.11676          GAMMA ( 3, 2 )=.05516       C@UPLING = 0.10999
Z( 4, 1 )= 1.49250          GAMMA ( 4, 1 )=.19759       C@UPLING = 0.38034

VAL( 1)=   80.47932
VAL( 2)=   77.71130
VAL( 3)=   78.98535
PEAK( 1) =  99.94876
PEAK( 2) =  102.38905
PEAK( 3) =  101.21535
  9.52068  11.06286
 -9.94876  11.06286
 12.28870  11.06286
-12.38905  11.06286
 11.01465  11.06286
-11.21535  11.06286
B( 2 )=-0.12480
B( 4 )= 0.47764
B( 6 )= 0.30856
B( 8 )=-0.42259
B(10 )=-0.63875
B(12 )=-0.23670
0 2
0 2
THE ERR@R C@EFFICIENT  2 IS @SCILLATING, APPLY FIX 1; because B(2)'s + 2.49 - - 1.82 - + 2.30
    GAMMA(1, 1 ) =  0.43440
    GAMMA(1, 2 ) =  0.27283
```

FIG. 25. (Continued)

```
     GAMMA( 1, 3 ) =  0.13238
     GAMMA( 1, 4 ) =  0.10605
     GAMMA( 1, 5 ) =  0.14783
Z( 1, 1 )= 1.83434          GAMMA ( 1, 1 )=.          COUPLING = 0.54179
Z( 1, 2 )= 1.83434          GAMMA ( 1, 2 )=.          COUPLING = 0.54179
Z( 1, 3 )= 1.83434          GAMMA ( 1, 3 )=.04793     COUPLING = 0.54179
Z( 1, 4 )= 1.66653          GAMMA ( 1, 4 )=.10605     COUPLING = 0.47052
Z( 1, 5 )= 1.34695          GAMMA ( 1, 5 )=.14783     COUPLING = 0.28934
Z( 2, 1 )= 1.83434          GAMMA ( 2, 1 )=.          COUPLING = 0.54179
Z( 2, 2 )= 1.83434          GAMMA ( 2, 2 )=.21528     COUPLING = 0.54179
Z( 2, 3 )= 1.18446          GAMMA ( 2, 3 )=.08444     COUPLING = 0.16769
Z( 3, 1 )= 1.83434          GAMMA ( 3, 1 )=.24090     COUPLING = 0.54179
Z( 3, 2 )= 1.12213          GAMMA ( 3, 2 )=.05755     COUPLING = 0.11472
Z( 4, 1 )= 1.47988          GAMMA ( 4, 1 )=.19351     COUPLING = 0.37305

VAL( 1)=   80.15573
VAL( 2)=   78.61826
VAL( 3)=   77.59271
PEAK( 1) =  100.08380
PEAK( 2) =  100.77907
PEAK( 3) =  100.58876
  9.84427  10.84749
-10.08380  10.84749
 11.38174  10.84749
-10.77907  10.84749
 12.40729  10.84749
-10.58876  10.84749
B( 2 )= 0.69358
B( 4 )=-0.38295
B( 6 )= 0.23612
B( 8 )=-0.09466
B(10 )=-0.43602
B(12 )=-0.09462
0 2
0 2
THE ERROR COEFFICIENT  2 IS OSCILLATING, APPLY FIX 1
     GAMMA( 1, 1 ) =  0.43758
     GAMMA( 1, 2 ) =  0.26906
     GAMMA( 1, 3 ) =  0.13149
     GAMMA( 1, 4 ) =  0.10774
     GAMMA( 1, 5 ) =  0.14964
Z( 1, 1 )= 1.83434          GAMMA ( 1, 1 )=.          COUPLING = 0.54179
Z( 1, 2 )= 1.83434          GAMMA ( 1, 2 )=.          COUPLING = 0.54179
Z( 1, 3 )= 1.83434          GAMMA ( 1, 3 )=.04438     COUPLING = 0.54179
Z( 1, 4 )= 1.67845          GAMMA ( 1, 4 )=.10774     COUPLING = 0.47606
Z( 1, 5 )= 1.35196          GAMMA ( 1, 5 )=.14964     COUPLING = 0.29273
Z( 2, 1 )= 1.83434          GAMMA ( 2, 1 )=.          COUPLING = 0.54179
Z( 2, 2 )= 1.83434          GAMMA ( 2, 2 )=.21271     COUPLING = 0.54179
Z( 2, 3 )= 1.19085          GAMMA ( 2, 3 )=.08711     COUPLING = 0.17292
Z( 3, 1 )= 1.83434          GAMMA ( 3, 1 )=.24203     COUPLING = 0.54179
Z( 3, 2 )= 1.11944          GAMMA ( 3, 2 )=.05635     COUPLING = 0.11235
Z( 4, 1 )= 1.48616          GAMMA ( 4, 1 )=.19555     COUPLING = 0.37669

VAL( 1)=   80.31802
VAL( 2)=   78.16516
VAL( 3)=   78.29124
PEAK( 1) =  100.01824
PEAK( 2) =  101.58523
PEAK( 3) =  100.89941
  9.68198  10.95474
-10.01824  10.95474
 11.83484  10.95474
-11.58523  10.95474
 11.70876  10.95474
-10.89941  10.95474
B( 2 )= 0.28324
```

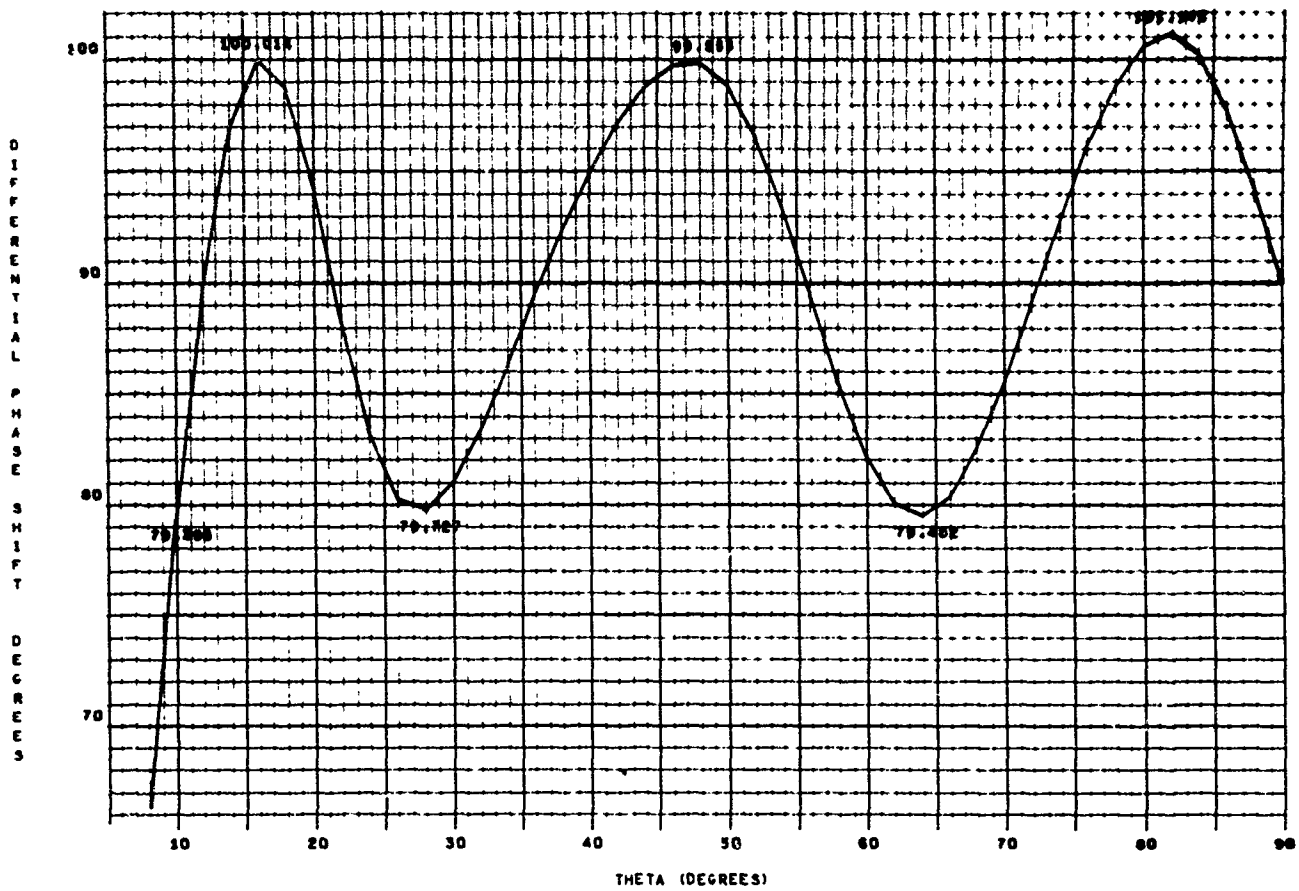
FIG. 25. (Continued)

```
B( 4 )= 0.04714
B( 6 )= 0.27264
B( 8 )=-0.25962
B(10 )=-0.53697
B(12 )=-0.16581
0 2
0 0
      NORMAL ERROR CORRECTION
    GAMMA(1, 1 ) =  0.44252
    GAMMA(1, 2 ) =  0.26589
    GAMMA(1, 3 ) =  0.13625
    GAMMA(1, 4 ) =  0.10321
    GAMMA(1, 5 ) =  0.14027
Z( 1, 1 )= 1.83434          GAMMA ( 1, 1 )=.              COUPLING = 0.54179
Z( 1, 2 )= 1.83434          GAMMA ( 1, 2 )=.              COUPLING = 0.54179
Z( 1, 3 )= 1.83434          GAMMA ( 1, 3 )=.05850         COUPLING = 0.54179
Z( 1, 4 )= 1.63160          GAMMA ( 1, 4 )=.10321         COUPLING = 0.45367
Z( 1, 5 )= 1.32632          GAMMA ( 1, 5 )=.14027         COUPLING = 0.27513
Z( 2, 1 )= 1.83434          GAMMA ( 2, 1 )=.              COUPLING = 0.54179
Z( 2, 2 )= 1.83434          GAMMA ( 2, 2 )=.22169         COUPLING = 0.54179
Z( 2, 3 )= 1.16862          GAMMA ( 2, 3 )=.07775         COUPLING = 0.15458
Z( 3, 1 )= 1.83434          GAMMA ( 3, 1 )=.24971         COUPLING = 0.54179
Z( 3, 2 )= 1.10128          GAMMA ( 3, 2 )=.04820         COUPLING = 0.09617
Z( 4, 1 )= 1.47772          GAMMA ( 4, 1 )=.19281         COUPLING = 0.37179

VAL( 1)=   79.39363
VAL( 2)=   79.72717
VAL( 3)=   79.48201
PEAK( 1) =  100.01439
PEAK( 2) =   99.85551
PEAK( 3) =  101.14183
 10.60637  10.40149
-10.01439  10.40149
 10.27283  10.40149
 -9.85551  10.40149
 10.51799  10.40149
-11.14183  10.40149
   THE DESIGN DOES NOT MEET THE SPECIFICATIONS -- FAIL
                                        EXIT BY 7

   EXIT 1:  IMPEDANCES ARE LESS THAN 1.0
   EXIT 2  TOO MANY PEAKS/VALLEYS IN RESPONSE CURVE
   EXIT 3  TOO FEW PEAKS/VALLEYS FOR ERROR ANALYSIS
   EXIT 4  DESIGN OF PHASE SHIFTER NOW COMPLETED
   EXIT 5  DESIGN OF COUPLER NOW COMPLETED
   EXIT 6  DESIGN OF COUPLER USED MAX. ALLOWABLE ITERATIONS
   EXIT 7  DESIGN OF PHASE SHIFTER USED MAX. ALLOW. ITERATIONS
   EXIT 8  A PEAK AND VALLEY ARE BEYOND BANDWIDTH EDGE
```

FIG. 25. End.



17.000 TO 1.0 BANDWIDTH PHASE SHIFTER

1.83434 1.83434 1.83434 1.83160 1.32632
0.94178 0.94178 0.94178 0.49586 0.27513

1.83434 1.83434 1.16862
0.94178 0.94178 0.15457

1.83434 1.10128
0.94178 0.09617

1.47772
0.37178

FIG. 26. Final Response Curve and Design Data of Phase Shifter.

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FINDING THE OPTIMUM DESIGNS OF ARBITRARY TEM-MODE QUADRATURE COUPLERS AND PHASE SHIFTERS, USING A DIGITAL COMPUTER

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13 ABSTRACT

ABSTRACT. This report discloses the full FORTRAN IV program (for an IBM 7094 digital computer) for the automatic design of arbitrary TEM quadrature couplers and differential phase shifters. The design is completely general in the sense that any number of coupled quarter wavelength sections, any nominal coupling value (or phase shift), and any design bandwidth of operation can be realized, although the user may specify any maximum coupling value in the design. This last degree of freedom in the specification to the machine, which is all-important in the physical realization of a theoretical design, is met by finding the proper number and types of tandem coupled junctions in the solution. This computer solution will be optimum. It will find the least ripple for the required bandwidth of operation for any (input) design complexity.

This report shows a complete flow chart of the total program. It also gives the special subroutines developed for automatic plotting of the coupler (or phase shifter) frequency-response functions. Various sample input data and machine outputs are also included.

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